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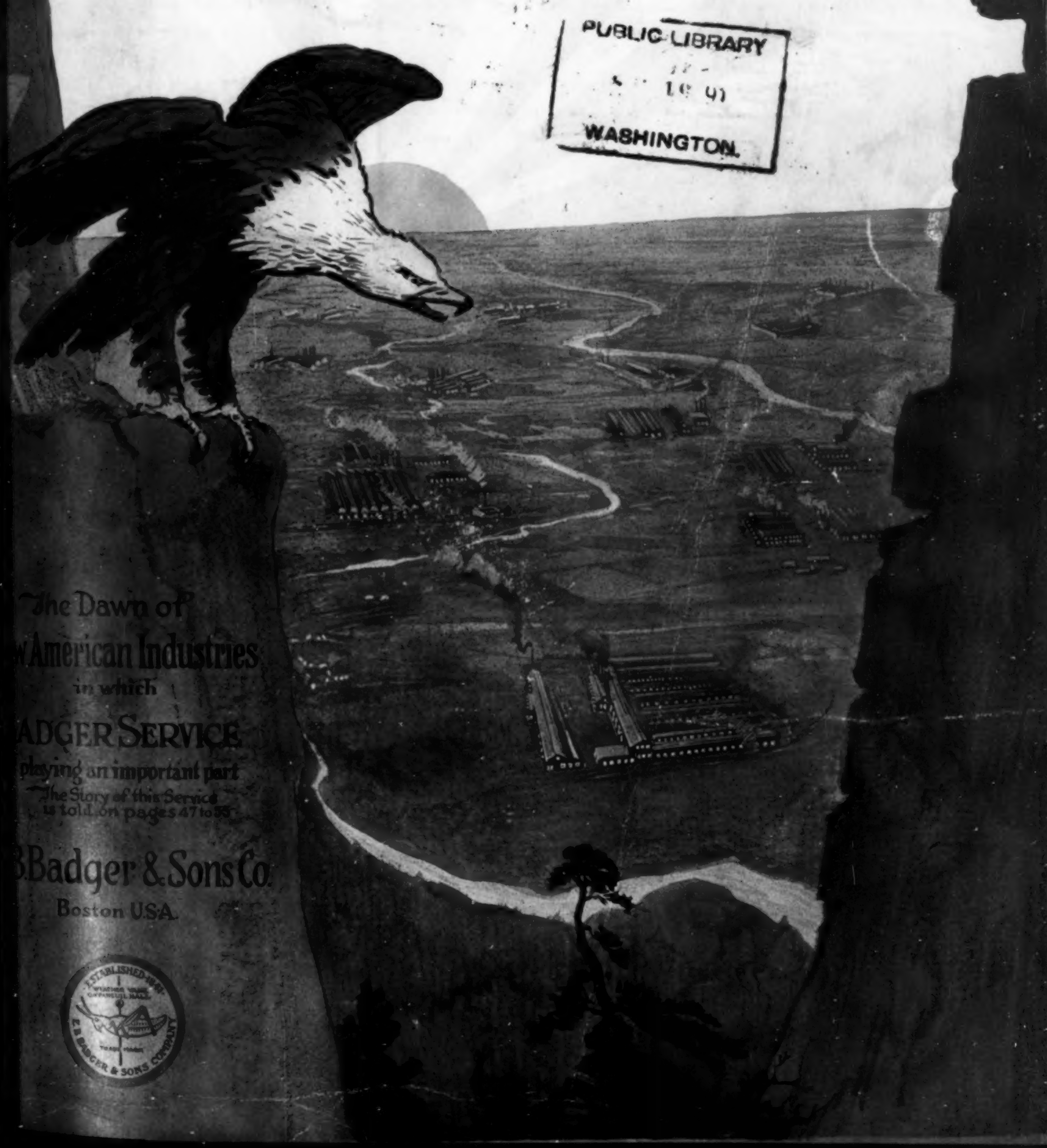

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S. Fischer, Ph.D., Western Editor.

J. Malcolm Muir, Manager.

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Chemists in Combination

Two great chemical societies meet in New York during the week of September 25 to 30, when the chemical exposition takes place: the American Chemical and the American Electrochemical Societies. That the major organizations should meet at the same time is reasonable and wise, provided the idea is not carried too far. If the Chemical Engineers and the Society of Chemical Industry were also to foregather on the same days there might be a little overlapping.

The number of chemical bodies is a sign of activity, and they spur one another on to avoid the ruts and grooves of dullness. It is very easy for a learned society to grow obese and heavy, to save its offices as rewards for age and prosperity among the incumbents and to meet for the achievement of dignity and admiration. It is pleasant to sit, fat-headed, in big chairs, to pass resolutions in praise of science and the learned and distinguished body of savants who grace the occasion by their inspiring presence—and let it go at that. Most of us are capable of drifting into just such complacency—if nobody bothers us and everything comes our way and there isn't anybody else to do better. But when learned societies multiply—within reason, of course—there is less likelihood of the substitution of mutual admiration for work One or two of them is bound to get busy, and with that the others also see that there is something to do.

We have in mind a certain society that had its origin and was located far away from here, with a name as imposing as that of the Sultan of Turkey and a charter as broad as that of the Manhattan Company, that for years and years did not contribute a single thing of real value to the public welfare. It had strong men and good men among its members, but the society did not do anything. It just lived along, blissfully content, assured of its social standing, and it served the purpose of its organization for public welfare by posing as the repository of transcendant wisdom. Suddenly a new condition arose and the service which it was supposed to render was called for. Then came trouble; pose the honorable body had; pose and poise, but it could not work; it was not set up to work. All of a sudden some technical men were drummed up apparently from nowhere at all, and the plain fellows, without honors and decorations, turned the trick and saved the day.

Now there is no present danger that such a situation will arise among our chemical societies. And yet, safety lies not so much in numbers as in the absence of vanity. Self-sufficiency is the killing thing. As soon as all the societies regard themselves as Perfect and Final Repositories of Knowledge, all will degenerate.

Indeed, as soon as any of them regards itself as having attained the pinnacle of desire, the feeling that it is accomplishing all that may be asked of it, so soon will its efficiency cease and the work have to be done by the others—as long as they last. Vanity and laziness are contagious maladies, and if one goes off there is the hazard that the others will follow. Fortunately the relations between the various chemical societies are full of friendliness and good will, and those in authority are men of catholic mind and disposition. Thus are petty jealousies avoided, out of which malice and anger grow. This is a matter of supreme importance, for anger kills the spirit of friendship and cripples progress. With all respect for every religious faith be it said, we have occasionally seen little towns with a dozen or more churches, and these seemed, somehow, to fail in the purposes of their organization, to fall short of establishing that brotherhood of man which leads to the Kingdom of God. A little investigation brought out the fact that each one was officially sure it was right and that all the others were wrong. It is the great good fortune of the scientific societies that they are free from these differences.

Professor Tyndall had a Scotch servant who served him faithfully to the end of his days. Every morning he rapped upon his door and said: "A-r-r-rise, Sir, a-r-r-rise! 'Tis seven o'clock an' ye have a g-r-r-reat wor-r-rk to do this day." Now science is so much greater than all the societies, its fields hither and yon are unploughed and uncultivated to so vast an extent, the battle against poverty and waste is so great and victory is so far away, that we have, all of us, a great work to do this day. And from the measure of the tasks which the chemical societies have set for their coming meetings, and the manner in which they are pulling together toward the distant goal, it would seem that they had called the old Scotchman's ghost and were listening to his message.

Made in America

There is a ring to "Made in America" that sounds pleasant in the ears of most of us—excepting importers. We like to read it and hear it, and are disposed to use the first person plural in reference to it, if it relates to that which succeeds. "We" have been leading the world in the iron and steel and copper and zinc and lead industries. "We" have been leading the world in electrochemical industries from the time that industrial Niagara Falls was founded. "We" have been leading in a number of industries of heavy chemicals, and if proof is needed that this leadership is not merely based on tonnage, but that this country can claim to have done its due share in technical improvements, the remarkable progress made in America in recent years in oil refining and cracking processes may be cited as just one example. But all these things are old stories, relating to industries in which this country always has had a decided natural positional advantage. But now since the European war has started, we have become independent of the foreigner even in a remarkable number of our industrial needs which formerly called for aid from abroad and with respect to which the natural advantage of this country was not so clearly defined as to encourage home production on a large scale.

At the risk of boasting let us consider some of the industries that have either been born or have greatly developed since the war began and the Euorpean sources of supply have been shut off. Without attempting to make a complete list or even a systematically classified list, and mentioning them only as they come to mind, there are barium compounds and potash, the latter in insufficient quantity, but growing. Among the most remarkable strides are those made in the manufacture of glassware, the permanent substitution of soda glass for the potash product in electric lamps, and the development of high-grade ware for laboratory and technical uses that was heretofore generally considered hopeless in this country. The same may be said of laboratory porcelain ware. Instead of making "brands" of special steels according to "recipes,"—a condition that had not entirely gone out of vogue when the war broke out—the leading companies are beginning to regard the making of specified steels as a necessary and proper part of their business. More ferroalloys than ever are made in this country to meet urgent requirements. The manner in which a great calcium carbide plant at Niagara Falls was switched over to produce ferrosilicon under stress of need was a shining example of efficiency and good sense. The fireworks man and the automobile wallah, as well as the lecturer on chemistry, need worry no more about the imports of magnesium. They are making plenty of it at several places.

This country has taken the lead in the production of radium and is likely to keep it. Crucibles were made of foreign clays because there was nothing that would serve the purpose to be had here with the old methods—until the United States Bureau of Standards found how to do it. Now, prime quality earthenware and stoneware is made here for nearly every purpose. The ruthless, wasteful and consequently wicked destruction of organic products by beehive coke ovens is diminishing by leaps and bounds, wherefore we should cease to sorrow rather than to boast. Munition works have become leading industries in many places, and this is the only legitimate business that we hope to see curtailed by the circumstances of peace. For a time the daily press was insistent that these should all be turned into coal-tar color works immediately after the war, but we have not heard much of it lately. Possibly this was to be accomplished by the engagement of a chemist to come and say "presto," and thus turn the trick. We know of no better method.

Instruments of precision designed for scientific and technical work are coming upon the market from local makers, and they are good. The dyestuff industry is getting out of its muddle. Many of the larger dye and print works are making their own aniline, aniline salt, and aniline and sulphur colors. The old names like Schoellkopf, National Aniline, Heller and Merz, Hudson River, etc., are familiar, but consider the new ones: Beckers, Swiss Color, Federal Dyestuff, Bull's Ferry, Neidich Process, Butterworth Judson—to mention only

a few of the new producers. We have not heard of a full list of alizarine or fast cotton colors developed as yet, although indigo is produced here synthetically on a small scale. Dulcinea and Hermione may not have been able to match all of their shades of ribbon since the war broke out, but we have seen flesh-colored hosiery that seemed almost too successful in its tint. The demand why "we" do not make our dyestuffs here has lost its imperative quality; "we" do make them.

The list of synthetic products now made in America is growing daily. Among others are salol and the salicylates, sodium benzoate, benzaldehyde and photographic chemicals by the dozen. Pharmaceutical products are coming along; not all of them by any means, but a great many of the standard ones that were formerly imported and a very engaging list of new ones.

The old chemical pot is boiling.

Steel Tonnages "Made in America"

In the case of nearly all of the wonderful improvements that have been made in the manufacture of steel in the past thirty years, a precise statement of "who did it first" would be likely to provoke a controversy The greatest single invention of them all, indeed, the pneumatic converter, furnished a subject of controversy for years. Bessemer's name was attached to it, but without Mushet's suggestion of the use of manganese it would not "work," while William Kelly of Pittsburgh, working in Kentucky, blew metal before Bessemer, but gave up his investigations because he feared that to develop the pneumatic converter would spoil the fairly lucrative business he already had.

When one thinks of "Made in America" in connection with iron and steel he is, however, on perfectly safe ground if he refers to tonnage. Whoever first suggested or practiced a certain improvement it is in the United States that the tonnages are made. In the production of pig iron here is a brief chart of the race. For many years the United States had made considerably more pig iron than Germany, but in 1875 Germany's metric tons slightly exceeded the gross tons of the United States. Then we have the following:

	United States, Gross Tons	Germany, Metric Tons	Great Britain, Gross Tons
1875	2,023,733	2,029,389	6,365,462
1890	United States passes Great Britain		
1890	9,202,703	4,658,451	7,904,214
1901	United States = Germany + Great Britain		
1901	15,878,354	7,880,088	7,928,647
1903	Germany passes Great Britain		
1903	18,009,252	10,107,901	8,935,063
1913	30,966,152 = 1.6 × Germany = 3 × Great Britain		

To continue the comparison for the period since the war started would not be illuminating as an index to the developments, but it may be noted that in 1915 the United States made as much pig iron as the rest of the world, and this year it will readily maintain the proportion.

While the United States has produced the large aggregate tonnages, it has also produced the large tonnages at individual works. It was in the American works that it was first decreed that the blast furnace should be the servant of the Bessemer converter, that if less silicon would shorten the blow the blast furnace must make the lower silicon, and thus wonderful records were made by American Bessemer converters. If mills could roll more steel by being made heavier they were made heavier and were given more power.

The development of the Lake Superior ore region is one of many illustrations of how American engineers established new tonnage concepts. When the Panama Canal was being dug the *Canal Record* published statements of steam shovel performance of which the engineers were proud, but for years the Lake Superior region had been doing better with its shovels. Underground mines on the Mesabi range were largely abolished, it being shown that in some instances it would pay to remove 2 ft. of overburden to uncover 1 ft. of ore. The ore-carrying capacity of lake vessels has been doubled almost from decade to decade, until now there is a record of 13,800 gross tons of ore for a cargo, loaded and unloaded in a very few hours. When the ore had to be carried a thousand miles, by rail, water and rail to furnace, it was necessary that everything should be done at the lowest cost per ton.

The American steel industry has given the world some wonderful products. There is the all-steel freight car, and later the all-steel passenger, the latter adopted partly because if accidents cannot be avoided it is well to make them as comfortable as possible. The latest steel coal cars are designed for 120 net tons carrying capacity, the work of a dozen cars abroad. Scores of skeleton steel buildings have been erected in the United States with more than 10,000 tons of structural steel in the framework. The American steel industry furnishes steel for an annual output of 1,400,000 automobiles, vastly more than the output of all the rest of the world, and for this automobile industry it furnishes not only steel of high physical quality, but steel of high surface finish, for the automobile industry is the father of many common descriptions of steel to-day.

In the new industrial future of the United States the steel industry is likely to progress even more rapidly than in the past, but on somewhat different lines. It will take more interest in the refinements of fuel and other economies and in the manufacture of more by-products. In these directions it will be true to its traditions of doing everything on a large scale. The ideas may come from abroad, with or without a "thank you!" but they will be carried out with courage on the broadest lines.

The Bureau of Mines and American Radium Production

Instances of successful and profitable cooperation between the federal government and private enterprise, for the promotion of scientific and industrial research, are not so numerous as to be called readily to mind. In fact the principle has been questioned so frequently, both by individual and organized bodies of professional consultants, that a fairly well defined sentiment exists against the idea. The general proposition is open to debate, of course, and exceptions may be recognized, particularly when such exceptions have become demonstrated facts.

The work of the Bureau of Mines and the National Radium Institute offers a peculiarly happy instance of successful cooperation of the type mentioned; and as the term of that cooperation is drawing to a close we may review the whole experience and observe its effect on American radium production.

The terms of the agreement, in brief, were these: The National Radium Institute was organized by Dr. James Douglas, Dr. Howard A. Kelly and others, for the purpose of securing radium for therapeutic use. The underlying motive was philanthropic. A supply of ore was provided through an agreement with officers of the Crucible Steel Company, who owned carnotite-bearing land in southwest Colorado, and who leased this land to the Institute on a 15 per cent royalty basis, with an agreement to purchase the uranium and vanadium byproducts. Then, in order to secure technical ability to operate the treatment plant, the Institute offered to furnish the Bureau with financial assistance to build and operate a mill for the treatment of 1000 tons of carnotite ore. The Bureau was to provide the services of certain of its staff for the technical control of the work. In addition to the opportunity thus afforded the Bureau to make a technological study of radium production, it was to receive any radium in excess of seven grams of anhydrous radium bromide produced from the 1000 tons of ore to be treated.

The results of three years' work now drawing to a close under this agreement may be recapitulated as follows: Approximately 1500 tons of ore and concentrate will have been treated when work ceases about the end of this calendar year. The National Radium Institute already has received its anticipated quantity of radium at a cost far below that indicated by the accepted market price. The Bureau of Mines also has obtained a part of its share and will ultimately receive a substantial quantity of the rare element for research purposes. Public benefits have accrued: An economical method of treatment has been developed for both ore and concentrate, and new radioactive methods of plant control have been devised. Some of these have been made public and all will be disclosed when the work is completed. The uranium-radium ratio has been proved to be in normal equilibrium in carnotite just as in pitchblende—an important fact for American producers. Valuable by-products of rare elements other than uranium and vanadium have been obtained for future study. Finally, as a sequel to the successful work with carnotite, an opportunity was recently offered to make a study of the concentration and treatment of low-grade pitchblende, which will add to our knowledge of radium production in this country. In this latter work the Colorado School of Mines was able to play a cooperative part through the use of its experimental mill.

Of course the personal element must not be overlooked in discovering reasons for the success of this venture. With men of less noble motives and narrower experience in the conduct of metallurgical enterprises, there would have been the chance of endless conflict and ultimate disaster. The times also were propitious with regard to public sentiment toward radium; while the unexpected cessation of production abroad undoubtedly stimulated an interest in American production of radium from domestic ores. In spite of original opposition which engendered more or less bitter feeling, we seem to have here an example of successful co-operation that justifies the contentions of its supporters. Whether it can be duplicated depends on so many conditions that it can not be taken as criterion.

The Future of Steel Consumption

The marvelous increase in the production and consumption of steel has always been the subject of wondering comment, where will it end? The rule of pig iron production doubling every decade having been so often referred to, while doubt has been expressed in recent years whether the rule is still in force, a precise statistical comparison may prove of interest. The production in the ten years ended last year having been 257,714,701 gross tons, a tonnage of 256,000,000 tons may be taken for the decade, as that figure is susceptible of convenient bisection. We therefore show 256,000,000 with its successive bisections in the first column in the following table, and the actual production in the second column, the statistics for the earlier years not being precise, although amply accurate for the purpose.

Pig Iron Production, Gross Tons

Ten years ended	By rule	Actual
1915	256,000,000	257,714,701
1905	128,000,000	148,658,012
1895	64,000,000	76,061,628
1885	32,000,000	32,319,295
1875	16,000,000	18,559,866
1865	8,000,000	7,951,047
1855	4,000,000	6,400,000
1845	2,000,000	3,000,000
1835	1,000,000	1,600,000

When the figures are considered according to this scheme the rule of doubling is seen to have been followed with remarkable fidelity. The confusing fact that contiguous decades do not show the progress well, is eliminated quite largely by making the comparisons between the alternating decades. The comparison of the decade just ended with the preceding one or two decades would suggest that the rule has lately been losing its force, but if we go back four decades or six decades we find an almost absolute harmony. In dealing with inanimate objects physical and chemical experiments frequently show a much larger discrepancy, and yet are considered valid than is shown by this investigation of what man, in his varying circumstances and moved by various emotions, has done.

The most common explanation of the rapid increase in iron consumption is that of "new uses." In its barest form that is, of course, no explanation at all. Why the "new uses"? To furnish a real explanation there would have to be discoveries, and those discoveries would have had to come by chance, and not through the compelling force of circumstances, which is the usual one with discovery and invention. If circumstances brought forth the new uses, then what were the circumstances? We have had new uses which did not "pan out."

The one great influence in the increase in the use of iron is, after all, a very simple one, readily understood. It is no more nor less than the continued and

rapid increase in the ability of the people to buy, by reason of their increase in numbers and their greater wealth. That, really, has made the skyscraper as well as the automobile. It has made the large consumption of steel in freight cars and locomotives as well as in metal furniture and farm implements. It is the one principle that explains the rapid increase in the use of iron and the one index that one can consider and weigh as to its force in causing a further continued increase in future in the consumption of iron in its various forms.

Labor Conditions After the War

What will happen to all the new chemical works and their business after the war? It is hard to tell what European labor conditions will be. Fighting embitters men and many who are heroic in a dash against an enemy and will watch and wait through long days and nights for a chance to shoot, may, and again may not, be able to work steadily when the raging and the tumult is over. Generally speaking, however, aside from the injury to the mind caused by shock and passion and anger (as brought out by Dr. Crile), military training is good training and fits men for team work.

In this country labor conditions are not improving. There has been bluff, chicanery and the very limit of stupidity practiced by many employers and by many organizations of labor. We have said before and we say it again that the obligation of an employer does not cease when his pay clerk passes out the pay envelopes. General welfare of the men and their families; housing, sanitation, schools and good living conditions must be looked after. One of the severest indictments against an employer that has come under our observation was a crippled father, a mother approaching her end from medical neglect, and a large family of children, all illiterate and under-nourished, returning from the works of a pompous, self-satisfied captain of industry to their native home in northern Italy. There isn't any excuse for this sort of a crime, and it has been practised by sheer omission all too often.

On the other hand, we find an apparently increasing number of labor leaders and agitators who know no gospel save that of hate and destruction; and they have learned the art of leadership. A passion for organization has arisen among the ranks of labor, and once organized, its leading purpose seems to be to strike and to destroy. A fashion of thought which is growing among them is to take all grievances out of the public. If an employer will not grant this, that or 'tother, but more especially if he will not give over the functioning of his authority and judgment in the administration of work which he is paid to supervise, then "pound the public" is the slogan, until he gives in.

A few successful threats have started a season of bluffing extraordinary, and of a kind that has not been dared heretofore. Four railway unions want an eight-hour day, and so their representatives tell the Congress of the United States that unless they get it they will set about to starve the people. And they proudly show their entire conspiracy whereby they have actually planned to inflict the ravages of hunger and disease upon the people of nearly the entire country unless their demand be granted. Then, instead of arresting the conspirators for planning such an heinous offense, as would have been done a dozen years ago, Congress obeys, and lets the men with the whip write the law! This is rank anarchy. Collective bargaining is just and right and proper, but collective blackmail and collective crime is no more to be endured than a single blackmailer or a single criminal. It is high time that we got this idea into our heads or the lash of the collective whip as a means of blackmail to gain power and advantage for self-organized groups of men, without reference to merit or justice, will destroy far more than property; it will destroy the liberties of all of us, rich and poor alike.

Now this is neither reasonable nor intelligent on the part of labor, nor is it a course to be expected, except as a result of a prevalent fashion or style of thought—and these are very contagious—or because men have been in charge of the affairs of corporations who may have had abundant executive ability but were lacking in character or were too timid to do right. But so long as labor goes by its abstract name and laborers are regarded as hands rather than as men, we cannot expect intelligence to abide in their organizations. The feeble-minded and incompetent are there because no other place has been found for them. There must be jobs for those who are below standard; jobs that pay a living wage and do not provide for the advancement available to entire men. Nobody wants feeble-minded workers in his establishment, but everybody that employs men in large numbers has them. He can't get rid of them; their fathers and brothers and sons will not let them go and the result is, now they are in the works, cutting down the pace and following the lead of every vicious notion that is presented to them, from breaking agreements to cracking skulls. Some place must be found for them and there is no change of turning them to profit; they are bound to be an expense in one way or another.

With the culls eliminated, a working staff can be organized that will beat the world, provided always there is the right measure and quality of brain tissue at the head. Some few concerns seem to be approaching this condition despite heavy labor costs and the reek of disorder in the air.

It behooves chemical industry to make its works attractive to those who earn their living there. Nothing helps more than an enthusiastic, loyal, well-paid working staff that believes in the company and is glad to work for it. We have seen a large part of the match industry in this country changed from an abode of misery, disease and desolation into a splendid, wholesome corps of good citizens who work in it. We find improvements developing among the workers in the iron and steel industries—in spots—that put old conditions to shame. And one of the first obligations of chemical industry, for its own benefit, is so to organize its work that its factory portals shall bid welcome to good men and true, to undertake their responsible tasks in conscience and in loyalty.

Readers' Views and Comments

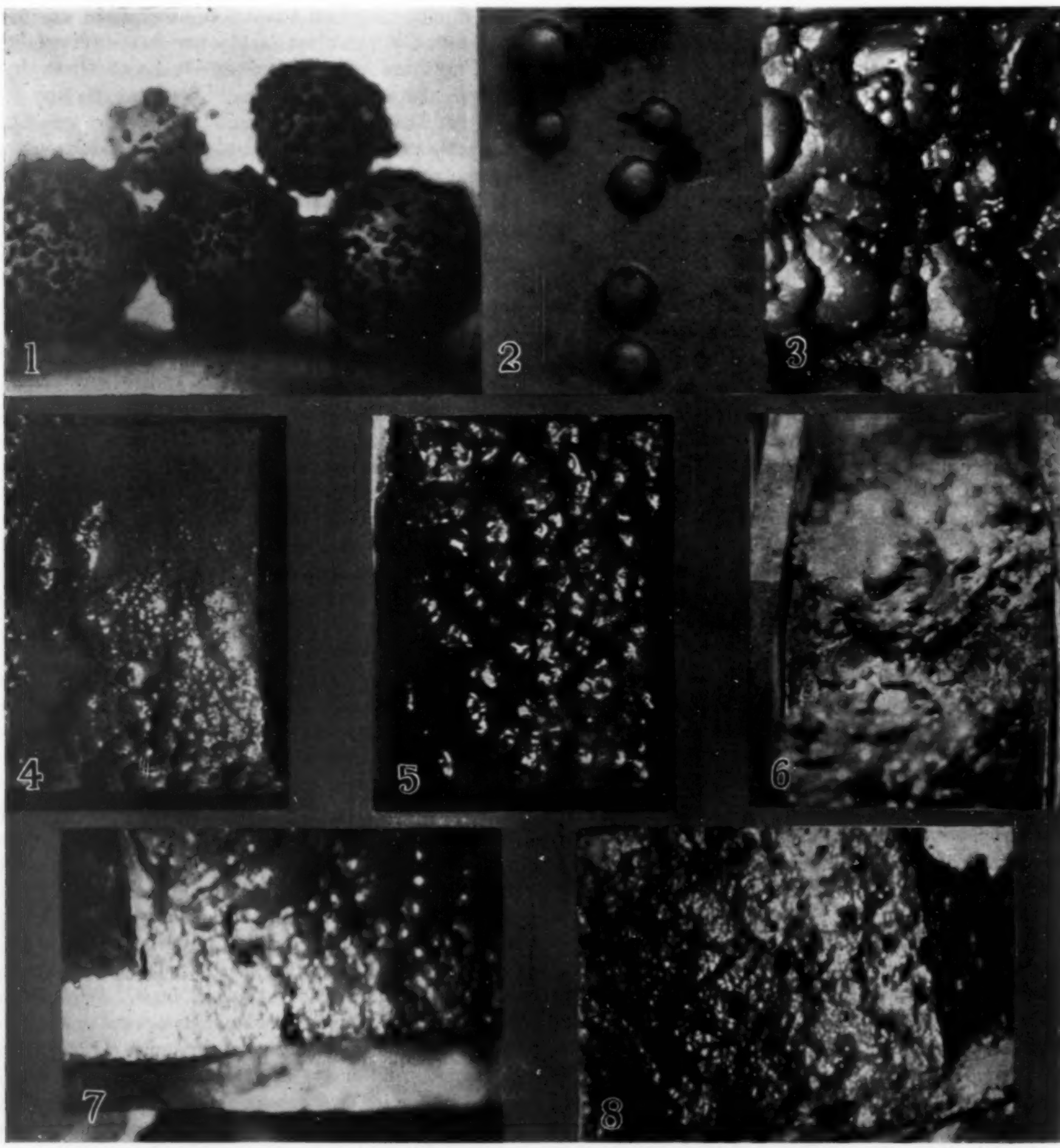
Flotation Bubbles

To the Editor of Metallurgical & Chemical Engineering

SIR:—In view of the great interest now taken in the flotation process, the photographs of flotation bubbles and bubble aggregates or froths, herewith reproduced, should be of interest.

Photographs 1 and 2 show the bubbles in the act of lifting the particles of minerals to the surface. They are cross-section views under water and were taken in a glass cell, using a B. & L. microscope and camera. Fig. 1 shows bubbles of a pine oil froth to which are adhering particles of cassiterite, Fig. 2 pine oil No. 6 froth, the bubbles lifting small particles of galena. The magnification in both cases is 40 diameters.

Photographs 3 to 8 show the froth in a small experimental machine; they were taken from above the machine. All factors affecting the froth were kept constant. The impeller was stopped just before taking the picture. This allowed the small bubbles of some froths to coalesce as shown in Fig. 3 to the formation of large bubbles and as shown in Fig. 5 to the formation of a small bubble scum. The ore used was a dolomitic lead ore. Fig. 3 shows cresylic acid froth, Fig. 4 coal tar



FIGS. 1 TO 8—FLOTATION BUBBLES

creosote froth, Fig. 5 pine oil No. 6 froth, Fig. 6, wood creosote froth (correct amount of oil), Fig. 7 wood creosote froth (with an excess of oil), and Fig. 8 shows wood creosote froth, the same as Fig. 7, after adding oil from water gas tar. The froth has become a scum.

CHAS. Y. CLAYTON.

School of Mines and Metallurgy,
University of Missouri, Rolla, Mo.

Sources of Metal Loss in Copper Refining

To the Editor of Metallurgical & Chemical Engineering

SIR:—In Mr. Lawrence Addick's paper on "Sources of Metal Loss in Copper Refining," in METALLURGICAL AND CHEMICAL ENGINEERING for July 1 the question of moisture in copper bullion is touched upon. The article in question implies that in the Australian copper on which these tests were first made the moisture came from contact with bilge water during shipment. There is every reason to believe that this moisture was bosh water, consequently refiners of copper have reason to look in copper shipped by rail for moisture, just as much as in that shipped by vessel.

DONALD M. LIDDELL.

New York City.

Pacific Coast Waterpowers and Electrochemical Possibilities

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of Aug. 1, 1916, page 115, appeared a report of a meeting on the Niagara Falls Power Famine. In this meeting Mr. F. A. Lidbury, manager of the Oldbury Electrochemical Co. and a Past President of the American Electrochemical Society, stated that electrochemical industries cannot establish on this Pacific coast because of the excessive transportation charges to the territory now supplied by Niagara. Conversely, from this it would appear that if there is a market tributary to this coast Niagara would be out of the running for this business as compared to a plant operating on the coast.

As a matter of fact the market for electrochemical products is world-wide, and the establishing of such a large and varied industry requires the condition of accessibility to the markets of the world, viz., cheap transportation, which condition is satisfied by a location in a good harbor on tide water. There are such locations on the Pacific coast.

The average annual imports of Chilian *nitrates* into San Francisco exceeds 30,000 tons. To manufacture 30,000 tons of lime nitrate containing about the same amount of nitrogen, would require approximately 40,000 hp.

That California in the year 1912 had orders in Norway for lime nitrate in excess of the entire output of one of the large plants is a statement published in the Hearings Before the House Committee on the waterpower bill.

Carbide.—There are probably more than 5000 tons of carbide used on this coast yearly. The establishing of new oxygen plants both in the States of Washington and California indicates an increasing use of carbide. In 1913 Chile imported from Germany over three and a half million kilos and Australia imported 14,155 tons, 85 per cent of which came from Norway and Sweden.

Ferro-alloys.—California is now shipping to the East chrome and manganese ore, and it is only a matter of reasoning that the ferro alloys could better stand high freight rates than the crude ore.

Cyanide.—The Pacific Coast is a more central distributing point for potassium or sodium cyanide than is Niagara.

Caustic.—At Pittsburg on San Francisco Bay there is now in operation a caustic and bleach plant established by people thoroughly conversant with and interested in similar plants in the East.

To the question: "Why do not electrochemical industries establish on this coast?" I would answer: "They are establishing."

E. P. KENNEDY,
President Speel River Project.

San Francisco, Cal.

The Determination of Chromium in Ferrochromium

To the Editor of Metallurgical & Chemical Engineering

SIR:—The following simple method for the determination of chromium in ferrochromium has proven, after a year's usage, both rapid and accurate.

The procedure consists in fusing the alloy with sodium peroxide, forming Na_2CrO_4, dissolving the melt, and, after boiling to destroy the excess of peroxide, which has a strong tendency to reduce chromium in acid solution, acidifying with sulfuric acid and titrating the resulting dichromate solution by the usual method with tenth normal ferrous sulfate solution. The following outline is worked out for ferrochrome which contains about 70 per cent chromium: For alloys of different composition one may modify the amount of sample taken or the size aliquot titrated within reasonable limits.

Weigh accurately one gram of finely pulverized alloy (50 mesh) and mix thoroughly with 25 to 35 grams sodium peroxide. This may be accomplished by stirring the mixture with a stiff platinum wire in either a nickel or an iron crucible of about 40 c.c. capacity in which the fusion is to be made. A layer of sodium peroxide is placed on top of the mixture and the crucible gradually heated over a Bunsen burner to a dull cherry red until the contents is entirely fused. The heat is now lowered, keeping the mixture molten at a very dull red, nearly black heat for fifteen minutes. Gradually raise the heat once more to a dull cherry red and then allow the crucible to cool.

Place the crucible and contents in a one-liter beaker with 250 c.c. of water. Cover and allow the reaction to proceed. When finished, remove the crucible and cover carefully, washing with hot water. Boil the contents of the beaker vigorously for about twenty minutes to destroy the excess of peroxide. Acidify with a considerable excess of ½ sulfuric acid and concentrate, if necessary, to a volume of about 300 c.c. Cool and transfer to a 500 c.c. volumetric flask and fill to the mark with water.

An aliquot of 50 c.c. is now titrated in the usual way against freshly standardized N/10 ferrous sudfate solution. This way be conveniently carried out by filling a 100-c.c. burette with the dichromate solution and titrating back and forth until a satisfactory end point is reached. The nitration may also be carried out by adding an excess of standard N/10 ferrous sulfate solution to a 50-c.c. portion of the solution prepared for analysis and titrating back to a blue end point with N/10 potassium permanganate solution. This end point may be properly identified by treating 50 c.c. N/10 $K_2Cr_2O_7$ (standardized by pure iron) plus sulfuric acid in the way described.

For the sharpest end point the solution must be perfectly cold.

One c.c. N/10 ferrous sulfate is equivalent to 0.001743 gm. chromium.

A. F. MACFARLAND.

John A. Crowley Company,
Detroit, Mich.

The Iron and Steel Market

While September has not brought more active conditions in the steel market than obtained in August it has brought an accretion of confidence that the time when the pressure on the mills for deliveries is a long way off. The scarcity of material for this year's delivery has been accentuated, partly by reason of additional buying and partly by reason of the hot weather being prolonged and causing the curtailed rate of production to obtain for a longer period than normal.

Steel prices have shown a further hardening tendency. Bars, plates and shapes are better established at the advances of a month ago. Iron and steel pipe has been advanced one point, or about $2 a ton, on butt weld sizes and two points on lap weld sizes, black, no change being made in galvanized. The new cards are dated Sept. 7. An advance in sheets is predicted for the near future, based on the expectation that the fourth quarter price on sheet-bar contracts will be $3 to $5 a ton higher than that obtaining for the third quarter.

Production of pig iron was a shade smaller in August than in July. The production in the first half of the year was 19,619,522 gross tons, but during July and August the furnaces fell 190,000 tons short of maintaining that rate, and the curtailed rate bids fair to continue through September. While October, usually a very favorable month for furnace operation, will doubtless show a heavy output, the prospect is that the official statistics will show smaller production of pig iron in the second half of the year than in the first half, although the second "half" of the year contains two days more.

There is no doubt that there was a considerable reduction in pig iron stocks during the first half of the year, while it is also a fact that new open-hearth furnaces have been completed month by month, whereby consumptive requirements certainly increase while it is impossible to make more pig iron. The general influence has not worked out thus far, perhaps, because the hot weather has curtailed the output of steel works very considerably since July 1. It is very easy to conceive an acute pig-iron scarcity developing within the next few months. That would quickly be reflected in the market. From the low point of December, 1914, basic pig iron at valley furnaces have advanced from $12.25 to $18, or $5.75, while billets have advanced from less than $19 to more than $45, or in excess of $26 a ton. If higher prices should be demanded for pig iron the steel works would have no difficulty in finding the money with which to pay.

Exports of iron and steel commodities that are reported by weight amounted to 496,000 gross tons in July, against 526,772 tons in June and 540,549 tons in May, the record month. Exports in the seven months totaled 3,112,000 tons, representing a rate of 444,000 tons a month, or 5,300,000 tons a year. In the same period British exports average 312,000 tons a month, and these exports were made up largely of material for the United Kingdom's allies. Until lately British exports were always greatly in excess of those of the United States.

Iron Ore

By a decision announced Sept. 5 by the Interstate Commerce Commission freight rates from Lake Erie docks to most Central Western points are revised, and on an average there is a reduction. New tariffs are to be filed by Dec. 1, and the new rates are to go into effect April 1, 1917. The rate to the Pittsburgh district is reduced from 88 cents to 82 cents. Monessen is taken out of the Pittsburgh district and given a rate of 96 cents, while on the other side Neville Island is taken out and given the 70-cent rate which is retained for Aliquippa. Johnstown, formerly with a rate of $1.02, is classed with Monessen. Wheeling is kept with Pittsburgh. The Pittsburgh rate was formerly 96 cents, but had been reduced to 88 cents when the commission ruled that the rate to Pittsburgh should not be higher than that to Wheeling, then 60 cents. Apart from the pecuniary importance of the decision the outstanding feature is the close application of the yardstick to the map. Only a few years ago the railroads were still insisting that the complicated rate structure would not permit of ton-mileage consideration of rates. The new rates as just stated are not the rates that will be published, as the carriers are required to segregate 6 cents for dock charges, from the rail of the vessel to the car, publishing this 6 cents as a separate rate. Apart from this 6 cents there is 10 cents that is regularly charged the vessel, making 16 cents for unloading direct ore. The commission ruled several years ago that its jurisdiction over iron ore, as interstate commerce, began at the rail of the vessel at lower lake dock.

Wild chartering has lately been done at $1 a ton clear to the lake vessel, against the regular rate of 50 cents established before the season opened, and it is understood there has been some chartering for next year at $1. The latest predictions are that Lake Superior ore may be advanced $1.25, instead of $1, for the new season, which would apparently give the shipper a net advance of 75 cents, allowing for the increased lake rate.

Iron ore shipments down the lakes in August amounted to 9,850,140 tons, or a gain of 100,000 tons over the July shipments. The season total is now 39,215,864 tons, indicating that about 62,000,000 tons can be moved down the lakes this season, with the usual movement of about 1,000,000 tons by all-rail to the old furnaces, plus about half a million tons consumption by the two Steel Corporation furnaces at Duluth, put in blast for the first time about the beginning of this year, making 63,500,000 tons in all. The record season's movement thus far was in 1913, just a shade under 50,000,000 tons.

Pig Iron Strong

The movement in pig iron has continued, but is more marked in foundry than in steel-making grades. All markets are firm, and some show an advancing tendency. Southern iron is up 50 cents, to $14.50, Birmingham, regaining half the loss it experienced earlier in the year, and the same is to be said of Chicago, which necessarily moves closely in harmony with Southern iron. Foundry iron at valley furnaces is up 25 cents, to $18.50. The furnaces may soon conclude they have sold enough of their output at prevailing prices. If a definite scarcity of pig iron should develop, as is far from impossible, the market would advance by dollars a ton rather than by fractions.

Unfinished Steel Very Scarce

Offerings of soft steel billets and sheet bars for this year's delivery are only occasional, and of small tonnages, the scarcity being as pronounced as at any time. The market is purely a nominal one, at say $45 to $50. One interest, perhaps more, is selling for first half shipment at $46 and upward. There are few consumers that could afford to pay $45 or $50 for steel, with finished steel prices at their present levels, but a finishing mill in position to profit by the premiums offered for early deliveries of some finished products could afford to do so.

The report seems to be correct that within the past fortnight two steel works have sold about 100,000 tons of billet discards for export, this following similar large

sales of more than a month ago, and it appears that the unwieldly accumulations of billet discards, arising in the manufacture of shell steel, are now quite well worked off. Some of the steel has been bought by consumers who desired the particular grade, but most of it has been taken by buyers who would much prefer to have ordinary soft steel.

Non-Ferrous Metal Market

Sept. 11.—Copper is strong and scarce on early shipments. Tin is unsettled, but prices remain fairly steady. Lead has improved and is in fairly good demand and spelter has also had a slight advance.

Copper.—The copper market is in a strong position and deliveries for the balance of 1916 are held at a higher figure. Scarcely any offers of prompt or September electrolytic are made by the producers, and 28 to 28¼c. is asked for the small amounts offered. Domestic buying is good for futures, October electrolytic being quoted at 27.75, with November and December deliveries at 27.25. Export business is dull at the present time, but inquiries for copper are being made by Russia.

Tin.—The tin market is in a very unsettled condition, due chiefly to the difficulty and delay in getting permits for shipments to this country. During the last two weeks there has been alternate activity and dullness and at present the market is dull and easy, with September and October Straits held at 38.40c. November arrivals at 38.35c., and December at 38c. Banca tin is about 1c. under these prices. Deliveries into consumption in August amounted to 4335 tons, somewhat less than the average so far this year.

Lead.—This market is at present in a pretty strong position. The trust price is still held at 6.50c. New York, with independents asking 6.60 and higher for spot deliveries. Sales to Japanese buyers were reported on Sept. 8, and these had the effect of stimulating the market somewhat. Futures are quoted at prices but very little under the spot price.

Spelter.—Buying was on a good scale last week following a previous dull period, and the market closed higher at the end of the week. Prompt and September spelter is quoted at 8¾ to 8⅞c., with fourth quarter at 8⅝c. There is difficulty in securing freight room for export shipments and the market abroad has advanced. Exports in August were large and amounted to 11,352 tons.

Other Metals.—*Antimony* is dull, with Chinese and Japanese held at 12c. No import business is reported on this metal. *Aluminum* continues steady at 61c, *magnesium* is quoted at $3.50 to $3.75 per pound, *platinum* at $60 per ounce, *quicksilver* at $76 per flask. *Silver* is higher at 68¼c.

Coming Meetings and Events

American Institute of Mining Engineers, Arizona, Sept. 18-23.

Association of Iron and Steel Electrical Engineers, Chicago, Sept. 18-22.

American Peat Society, Washington, D. C., Sept. 21-23.

Mining and Metallurgical Society of America, New York Section, New York, Sept. 21.

Second National Exposition of Chemical Industries, New York, Sept. 25-30.

American Chemical Society, New York, Sept. 25-30.

American Electrochemical Society, New York, Sept. 28-30.

Technical Section, American Paper and Pulp Association, New York, Sept. 25-30.

American Gas Institute, Chicago, Oct. 17-20.

American Society of Mechanical Engineers, New York, Dec. 5-8.

American Institute of Chemical Engineers, New York, Jan. 10-13, 1917.

The New President of the Colorado School of Mines

Mr. Howard C. Parmelee, for the past six years Western editor of this journal, has been elected president of the Colorado School of Mines. In extending to him our congratulations, in which we are sure his many friends in all parts of the country will join us, we feel we are not overstating the case if we say that the famous Colorado School is equally to be congratulated on the selection of its new president.

Mr. Parmelee was educated at the University of Nebraska, where he received the degree of B.S. in 1897 and A.M. in 1899. He entered the employ of the Union Pacific Railroad as assistant chemist in their Industrial Laboratory in 1900. From 1901 to 1903 he was chemist

HOWARD C. PARMELEE, PRESIDENT, COLORADO SCHOOL OF MINES, GOLDEN, COLO.

at the Globe plant at the American Smelting & Refining Company. From 1903 to 1906 he was consulting chemist at Denver, Col. He entered editorial work in 1905 as editor of the *Mining Reporter* and continued in this position until 1907. From 1908 to 1910 he was editor of the *Western Chemist and Metallurgist.* In 1910 he became Western editor of METALLURGICAL AND CHEMICAL ENGINEERING.

His editorial work gave him wide acquaintance among metallurgical and chemical engineers throughout the country and provided him with an insight into the educational demands of those industries. This was further aided by his great activity in the work of technical societies. Mr. Parmelee was one of the organizers of the Western Association of Technical Chemists and Metallurgists and general secretary of the organization for five years. He is also one of the organizers of the Teknik Club of Denver and its secretary since its organization, about six years ago. He is a member of the American Institute of Mining Engineers, a manager of the American Electrochemical Society, and the president of the Colorado Scientific Society for the year 1916. He has been elected to several honorary scientific societies, Sigma Xi, scientific fraternity, at the University of Nebraska; Tau Beta Pi, engineering fraternity, at the Colorado School of Mines; Alpha Chi Sigma, chemical fraternity, at the University of Colorado.

While we sincerely regret the loss of Mr. Parmelee as active Western editor of this journal, we are glad to state that he has consented to stay with this journal in an advisory and consulting capacity to introduce his successor as Western editor, Dr. S. Fischer, Jr., into the work and insure continuity of editorial effort.

These have been six happy years of friendly editorial co-operation. We cannot express our wishes for Mr. Parmelee's future career better than in the hope that he will meet the big task before him as president of the Colorado School of Mines with the same resolute courage, the same genial resourcefulness, and the same decided success which have characterized his work in the past.

Program of New York Meeting of American Chemical Society

The general program of the fifty-third meeting of the American Chemical Society, which will be held in New York City, Sept. 25 to 30, during the week of the Exposition of Chemical Industries, is as follows:

Monday, Sept. 25

2.00 p. m.—Official opening of Exposition, addresses by Dr. Chas. H. Herty, Dr. Francis A. J. Fitzgerald and Dr. Arthur B. Daniels.

4.00 p. m.—Council meeting, Chemists' Club.

7.30 p. m.—Council dinner, Chemists' Club.

9.00 p. m.—Council meeting, Chemists' Club.

Tuesday, Sept. 26

10.00 a. m.—General meeting of the society at Horace Mann Auditorium, Columbia University, 117th Street and Broadway. Addresses of welcome by Mayor Mitchell of the city of New York, President Butler of Columbia University. Response by President Herty, followed by general papers.

2.00 p. m.—Public meeting, Horace Mann Auditorium, Columbia University. Addresses by speakers of national reputation (to be announced). Presidential address by Dr. Herty.

8.00 p. m.—Reception at Hotel Astor. Members American Electrochemical Society invited.

Wednesday, Sept. 27

Morning.—Divisional meetings, Columbia University, Symposium on Colloids (theoretical).

Afternoon.—Two industrial conferences. One at the Chemists' Club on American Dyestuff Manufacture and one at Grand Central Palace on Electric Steel.

Thursday, Sept. 28

Morning.—Divisional meetings, Columbia University. Symposium on Colloids (applied).

Afternoon.—Two industrial conferences. One at the Chemists' Club on Industrial Alcohol, Acetone, and Formic Acid, and one at Grand Central Palace on Glassware and Porcelain.

Evening.—Invitation Smoker of the American Electrochemical Society.

Friday, Sept. 29

Morning.—Divisional meetings, Columbia University, Symposium on Occupational Diseases in Chemical Trades.

Afternoon.—Two industrial Conferences. One at the Chemists' Club on Medicinal Chemicals, and one at Grand Central Palace on Manufacture of Paper Pulp and Byproducts.

8.00 p. m.—Subscription Banquet at Waldorf-Astoria, members and wives, $3.50. Guests at cost. The members of the American Electrochemical Society and the Technical Section of the American Pulp & Paper Industry are invited, with price same as to members American Chemical Society.

Saturday, Sept. 30

Morning.—Meetings of divisions. Industrial Conferences at Chemists' Club on Oils and Motor Fuels. Industrial Conferences at Grand Central Palace on Miscellaneous Chemical Industries, and Convertibility of Plant.

11.00 p. m.—Exposition closes at Grand Central Palace.

Program of New York Meeting of American Electrochemical Society

The program of the fall meeting of the American Electrochemical Society which will be held from Sept. 27 to 30, in New York, in conjunction with the Second National Exposition of Chemical Industries, includes many interesting technical and social features. The hotel headquarters will be at the Hotel Astor.

On Thursday and Friday afternoons inspection of the exhibits at the Exposition will be the feature. On Thursday evening a complimentary smoker will be held at the Hotel Astor, to which the members of the American Chemical Society and all other visiting chemists and engineers are invited. On Friday evening a subscription dinner will be held at the Waldorf Astoria under the auspices of the American Chemical Society, to which members of the American Electrochemical Society are invited. The charge will be $3.50 per plate for members of either society and their ladies. For guests the charge will be cost. On Saturday an all-day excursion will be held up the Hudson by the American Electrochemical Society. Members of visiting societies are invited up to the capacity of the boat.

The detailed program is as follows:

Wednesday, Sept. 27

Electrochemical day at the Exposition, Grand Central Palace.

8.00 p. m.—Individual theater parties.

Thursday, Sept. 28

9.30 a. m.—Reading and discussion of papers.

O. P. Watts and P. L. DeVerter, The Protection of Iron by Electroplating.

E. A. and L. T. Richardson, Atmospheric Corrosion of Commercial Sheet Iron.

O. C. Ralston and C. E. Sims, The Electrolytic Recovery of Lead from Brine Leaches.

H. J. Morgan and O. C. Ralston, Electrolytic Zinc Dust.

W. E. Koerner, Electrolytic Behavior of Tungsten.

S. Fischer, Jr., Electrolysis of Vanadium Salts.

L. D. Hammond, The Electrodeposition of Nickel.

F. C. Mathers and E. G. Sturdevant, Current Efficiencies in Nickel Plating Baths with Rotating Cathodes.

W. Blum, Deposition of Copper in Electrotyping Baths.

12.30 p. m.—Luncheon at Hotel Astor.

2.00 to 6.00 p. m.—Visiting the Exposition.
8.00 p. m.—Complimentary smoker at Hotel Astor.

Friday, Sept. 29

9.30.—Reading and discussion of papers.
C. F. Burgess, Characteristics of Small Dry Cells.
L. C. Turnock, Effect of Temperature on the Performance of the Edison Storage Battery.
Carl Hering, High-Temperature Heat Developed during Electrolysis.
F. A. Fahrenwald, The Possibilities of Developing Superrefractory Materials for Incandescent Lighting.
H. Schlundt, T. H. Leaming and Julius Underwood, Composition of the Ionization Currents Due to Equal Quantities of Radium Emanation.
M. J. Brown, A New Method for the Study of Silver-Peroxynitrate.
W. C. Moore, The Vosmaer Phenomenon.
Grinell Jones and M. L. Hartmann, The Equilibrium between Bromine and Postassium Bromide Solutions at 0 Deg.
12.30 p. m.—Luncheon.
8.00 p. m.—Subscription banquet at Waldorf Astoria under the auspices of the American Chemical Society.

Saturday, Sept. 30

All-day excursion up the Hudson River. Details will be given out at the registration booth, where also the tickets for the smoker and the excursion will be obtained.

The arrangements for the meeting are in the hands of the New York Section of the American Electrochemical Society, of which Dr. Colin G. Fink is chairman and Mr. J. Malcolm Muir, 239 West Thirty-ninth Street, is secretary. Mr. John V. N. Dorr is chairman of the Finance Committee.

Second National Exposition of Chemical Industries

When the Second National Exposition of Chemical Industries opens on Monday, Sept. 25, the public will have an opportunity of seeing collected together under one roof a remarkable collection of apparatus, machinery and products representative of chemical and allied industries. The educational value will be immense, as many processes will be demonstrated in actual operation and moving pictures of various industries will be shown. This is not an exposition which only the technically trained man can enjoy; on the contrary, everyone can find much of interest and value.

One exhibitor will operate a miniature plant making sulphuric acid by the contact process. The American dyestuff industry will be well represented, with raw materials, intermediates, finished dyes and dyed products shown by most of the important companies. One exhibitor will show the process of making one class of dyes, and will operate a complete refrigerating plant for this purpose. One group of chemical companies will show every step in the dyestuff industry—coal, coal-tar crudes, intermediates, dyes, and the alkalis, acids and salts necessary in the various steps.

Electrolytic cells for making caustic soda, chlorine and sodium hypochlorite form another interesting feature. The products of these cells will be shown, and also some of the uses of chlorine in chlorine derivatives, such as carbon tetrachloride, chlorbenzol, etc. A nitric acid condenser will be in operation, the Cottrell electrical precipitation process of removing solids and liquids from gases will be demonstrated, and it will be shown how it can be applied to the recovery of dust in cement plants.

The other features, including motion pictures, the Bureau of Mines exhibit, the paper and pulp section, the Southern opportunity section, etc., which have already been commented upon in these columns, will prove most interesting to everyone. There are over 50 per cent more exhibitors this year than last, and the attendance will undoubtedly be almost double. The programs of the meetings of the American Chemical Society and American Electrochemical Society, which will be held in conjunction with the exposition, will be found elsewhere in this issue.

Status of New Tariff Law on Dyestuffs

The dyestuff tariff has at last become a law. The Revenue Bill H. R. 16,763, containing the dyestuff schedule, passed the Senate and House after going to conference last week, and was signed by the President on Friday, Sept. 9. It is a good bill in many respects; in one respect it cannot be considered fair to the dyestuff industry in this country, and it may be robbed of its effectiveness by one clause.

The bill as finally adopted was a compromise measure. Coal-tar crudes are admitted free; intermediates are taxed 15 per cent ad valorem and 2½ cents per pound specific; finished dyes, excepting alizarine and alizarine dyes, anthracene and carbazol, natural and synthetic indigo and all indigoids, medicinals and flavors, are taxed 30 per cent ad valorem and 5 cents per pound specific duty. The exceptions noted are taxed only 30 per cent ad valorem.

The bill as it originally passed the House was not entirely agreeable to the Senate, and it was the subject of considerable debate.

A hearing was given by the Senate Finance Committee during the last week in July to three members of a sub-committee of a larger committee originally appointed at a joint conference held in New York in March, (at which were present representatives of practically every industry affected by the dyestuff situation, including manufacturers of coal-tar products and all classes of consumers). This sub-committee made the following recommendation to the Senate committee:

"It is urgently recommended that lines 23 and 24 at the bottom of page 89, and lines 1 and 2 at the top of page 90 (Title V, Sec. 401), reading as follows: '(except natural and synthetic alizarine, and dyes obtained from alizarine, anthracene and carbazol; and natural and synthetic indigo and all indigoids, whether or not obtained from indigo)' be omitted. Otherwise the sincere and rational attempt of H. R. 16,763 to establish a coal-tar industry in this country is liable to be entirely frustrated by that parenthetical exception."

The Senate struck out this clause, and provided that the bill be not operative until after the war, and the bill went to conference. After consideration by the conference committee the clause was put back with medicinals and flavors added, and the bill was made effective at once. It finally passed both Senate and House in this form. After five years a yearly reduction of 20 per cent in duty is to be made, and unless the American industry reaches 60 per cent of our consumption in five years the duties become ineffective.

Further parts of the argument presented to the Senate committee by the sub-committee above mentioned, representing practically all the large producers and consumers, are worthy of earnest consideration. The argument continues as follows:

"The bill, after imposing a general 30 per cent duty on colors and dyes embodies in Section 401 the specific rates designed to encourage the foundation of this industry in the United States. This section imposes for a period of five years or more a special duty of 2½c. per pound on intermediates enumerated in Group 2, and 5c. per pound on the finished colors and dyes enumerated in Group 3. But, un-

fortunately, the parenthetical exception above referred to cuts out from this special 5-cent duty 'natural and synthetic alizarin and dyes obtained from alizarin, anthracene, carbazol and natural and synthetic indigo and all indigoids, whether or not obtained from indigo.'

"The class of colors thus excepted from the operation of the act constituted 27 per cent in money value of all the dyes sent out from Germany to us in the year 1913 and German exports alone represented more than 80 per cent of the U. S. A. consumption of all colors in that year.

"The terms of the bill provide that the special duty shall cease unless an American industry shall have been built up in five years' time capable of furnishing 60 per cent in value of the country's consumption. This arbitrary deduction of 27 per cent of the industry will make the attainment of 60 per cent of the total, a practical impossibility.

"Nearly eight million pounds of indigo, 20 per cent paste, are annually imported at a value of one and a half million dollars; this is by far the most important single color imported, and no other color approaches a million dollars in value. The two classes—alizarin and indigo—already represent nearly 16,000,000 pounds by weight of our color imports out of a total of fifty million pounds, and if they were permitted to reach our shores at one-half the duty imposed on the others they would soon represent nearly all of our colors. Dyes obtained from anthracene and indigoids comprise every shade of color in the rainbow. The colors thus excepted by the bill may be used on cotton, silk, wool, leather, in making paints or for any other purpose for which the strictly aniline colors may be used. Taken on the average, the colors thus excepted sell at lower prices in the form in which they are sold than the so-called 'anilines.'

"Nearly all of the excepted colors are made either with or by a combination of anilin oil and salts. Turkey red, it is true, may be made without using anilin and indigo may be made without using it, but as a matter of fact, one-half of the indigo in the world is actually made by using anilin and (however made) 70 per cent of the weight of indigo consists of anilin in its final analysis or composition.

"And it is now recognized that the cheapest and most effective way to make indigo is by the use of anilin. And yet under this exception indigo made with anilin would escape the extra duty or surtax. All the other excepted colors contain as much as 30 per cent of their weight in anilin oil or its equivalent.

"And so, as was stated above, these colors dovetail into one another and it will be chimerical to expect to build up an anilin color industry in this country by a specific tariff whilst thus exposing it to attack from colors that contain anilin, compete with anilines and yet under the exception will not be classed as anilin colors.

"Furthermore, it may be stated that for the amount of indigo imported into this country in 1913 there was required 1,000,000 lbs. or 500 tons of anilin oil in its production, and the total anilin oil consumption of the country before the war was but 4,000,000 lbs. This exception, therefore, practically takes back with the left hand what has been given with the right. It presents the anomaly of attempting to build up that most important coal tar industry by a temporary dike or barrier and leaving the dike wide open over 27 per cent of its length.

"The duties provided by the act are at the best barely sufficient to offset in normal times the handicap of German priority and pre-eminence.

"The exclusion of the colors in question would open a way to evade the spirit of the law and would cause endless disputes calling for Treasury interpretations. The consumer would find himself forced to question the derivation of every color imported in the hope that it would be found to be included in the excepted class. Expert witnesses could show that blacks, blues and 90 per cent of all colors may be produced from alizarin, anthracene, indigo and carbazol. The European makers would immediately develop colors produced from the privileged group which have many superlatively good qualities, and soon the new tariff would be found almost as inefficient in building up this industry as we have just found to our cost that the old tariffs have been.

"The collateral importance of this industry must not be overlooked.

"The coal-tar industry has a direct bearing on the steel industry as also on the high-explosives industry, and this last is absolutely essential to national life and safety.

"Unless the coal-tar color industry can be put on a sound, independent and paying basis in this country, it will be impossible for the country to become independent of the world in the matter of those high explosives which are essential for military purposes.

"During the past thirty years a 30 per cent *ad valorem* duty on so-called anilines, but leaving indigo, anthracene etc., on the free list, has utterly failed to produce any sort of coal-tar color industry in this country except a very small industry which depended on imported intermediates. There is no foundation whatever for the belief that a 30 per cent duty which was ineffective in the case of anilines would be effective to create such an indigo and anthracene industry in this country. The color industry is and should be considered as a whole. If exceptions are made which are to be wholly or partly duty free they would soon grow to be of more importance than the items not excepted, and this could have only one effect—to defeat the very object of the bill. No one would be tempted to invest money in making aniline colors so long as he could be exposed to competition by another group or class of colors paying a much lower duty."

Representative Kitchin of North Carolina, chairman of the House Ways and Means Committee, led the fight in the conference committee against the specific duty on alizarin, indigo, medicinals and flavors, and Ceasar Cone of the Proximity Manufacturing Company of North Carolina, one of the largest users of indigo in the country, persistently fought the duty on these products. Thus it might be said that one factory has won out against consumers and manufacturers employing 2,000,-000 people.

The dumping clauses in the section on unfair competition are first-class. Provisions are made for the first time, controlling imports and subjecting importers to all the restrictions of American manufacturers. The anti-dumping clauses are practically the same as when the bill passed the House and Senate before going to Congress. They make it unlawful for any person to import goods and sell them at a lower price than the actual market price in the country of their production.

The actual text of Group III and Sections 83 and 84 are given below. Group I contains a list of the coal-tar crudes—these are admitted without duty—and Group II contains a list of dutiable intermediates. These are omitted.

"Group III. All colors, dyes, or stains, whether soluble or not in water, color acids, color bases, color lakes, photographic chemicals, medicinals, flavors, synthetic phenolic resin, or explosives, not otherwise specially provided for in this title, when obtained, derived, or manufactured in whole or in part from any of the products provided for in groups I and II, including natural alizarin and indigo, and colors, dyes, or color lakes obtained, derived, or manufactured therefrom, 30 per centum ad valorem.

"Sec. 83. That on and after the day following the passage of this act, in addition to the duties provided in section 82, there shall be levied, collected, and paid upon all articles contained in group II a special duty of 2½ cents per pound, and upon all articles contained in group III (except natural and synthetic alizarin, and dyes obtained from alizarin, anthracene, and carbazol; and natural synthetic indigo and all indigoids, whether or not obtained from indigo and medicinals and flavors), a special duty of 5 cents per pound.

"During the period of five years beginning five years after the passage of this act, such special duties shall be annually reduced 20 per centum of the rate imposed by this section, so that at the end of such period such special duties shall no longer be assessed, levied, or collected; but if at the expiration of five years from the date of the passage of this act, the President finds that there is not being manufactured or produced within the United States as much as 60 per centum in value of the domestic consumption of the articles mentioned in groups II and III of section 82, he shall by proclamation so declare, whereupon the special duties imposed by this section on such articles shall no longer be assessed, levied, or collected.

"Sec. 84. That paragraphs twenty, twenty-one, twenty-two and twenty-three and the words 'salicylic acid' in paragraph one of Schedule A of section 1 of an act entled 'An act to reduce tariff duties and to provide revenue for the government, and for other purposes' approved October 3, 1913, and paragraphs 394, 452 and 514, and the words 'carbolic' and 'phthalic,' in paragraph 387 of the 'free list' of section 1 of said act, and so much of said act or any existing law or parts of law as may be inconsistent with this title are hereby repealed."

Glimpses of New Pacific Coast Industries in the Making

Impressions From a Flying Editorial Trip to California

To write down the impressions received on an all-too-short trip to California might seem preposterous, if it were not for the fact that it was just one more trip in a series. While none of these trips was extended enough and thorough enough to permit a complete detailed sketch to be made of what was seen, they all together have left a very distinct moving-picture effect of new Pacific Coast industries in the making. To bring this point out clearly is the object of this note, while more complete accounts of the various new industries are reserved for future issues from the pen of men directly connected with the different undertakings.

After a very hot trip through the Middle West a first stop was made in Denver. Through the courtesy of Dr. R. B. Moore of the Bureau of Mines we visited the radium plant operated jointly by the Bureau and the National Radium Institute. It is a very business-like affair and gives an unexpected impression of bigness of plant and operation. The process was described in detail in a paper by Dr. Charles L. Parsons in our Vol. XIV, page 51 (Jan. 1, 1916). The work will soon be completed and the plant will then be sold or dismantled. We comment on some aspects of the radium work of the Bureau of Mines in an editorial in this issue (page 275).

At Salt Lake City another stop was made and we enjoyed a very interesting forenoon at the University of Utah, where in the Mining Building the station of the Bureau of Mines, under Dr. Dorsey A. Lyon, has its headquarters. We hope to publish in one of our next issues an account from Dr. Lyon's pen of the very far-reaching and manifold researches carried out under his direction during the past two years. These researches have covered the most varied subjects, from flotation to electrolytic zinc and lead, and the recovery of zinc from low-grade ores by igneous concentration, and many other problems. It is a very well equipped laboratory, with some ingeniously designed home-made apparatus. From Dr. Lyon's laboratory more than one well-trained engineer has gone into metallurgical practice, and the industry has been the gainer. One of his most notable co-workers who is still with him is Mr. Oliver C. Ralston, well known to our readers by his work on flotation and electrolytic zinc and lead.

The University Club of Salt Lake City, at which we had the pleasure to lunch with Dr. Lyon, deserves a notice, as it represents a realization of what has been considered an impossibility in other cities. There is a very cozy clubhouse in the best residential street, and yet in most immediate neighborhood of the business life of the city, with library and roof-garden, and all appointments which make a clubhouse homelike. No wonder the financial conditions of the club are said to be the most flourishing of any club in the State.

From Salt Lake City we went straight to San Francisco, and the first side trip to study new developments was made to the Pitt River in Shasta County.

Electrochemistry Along the Pitt River

Pitt is a station, nothing more, on the Shasta route, a little beyond Redding, a night's ride from San Francisco. It serves as the starting point of a small so-called railroad line along the Pitt River up to Bully Hill. One of the stations along the scenically beautiful road is Heroult on the Pitt.

ELECTROLYTIC ZINC AT BULLY HILL

Bully Hill is a famous old mining and smelting center. There are many indications of the primitive operations from early gold mining days up the Pitt River. There is also the big Bully Hill copper smelter, owned by the General Electric Company, but not in operation now on account of the suit brought by the government for damage done by fumes to vegetation. There we had the pleasure to meet our good old friend Mr. C. A. Hansen, who has temporarily forgotten his old love, the electric furnace, and is busily and enthusiastically engaged in making electrolytic zinc in a large-scale experimental plant. A very interesting account of some of his work at Bully Hill was given by him in our issue of Feb. 1, 1916 (Vol. XIV, page 120). He is not now using rotating cathodes, but some from his former work were there for inspection. It is interesting to note that different ores respond differently to the electrolytic process. Some curious problems with respect to addition agents have come up. The process is to be used on a large scale at the Mammoth Smelter at Kennet (midway between Pitt and Redding), and Mr. Handley of this company has done considerable work on the process.

There is no doubt that electrolytic zinc is attracting very considerable attention. The number of metallurgists from various zinc companies we met at Bully Hill was significant in this respect. We were especially delighted to meet again at Bully Hill the distinguished general manager of Amalgamated Zinc, Ltd., of Broken Hill, Australia, Mr. Herbert W. Gepp.

WHERE THE McCLOUD CREEK JOINS THE PITT RIVER

After much talk with many zinc experts, not all of the same opinion by any means, it would seem no rash prediction to say that electrolytic zinc has come to stay for good.

NOBLE ELECTRIC STEEL COMPANY

Midway between Bully Hill and Pitt lies Heroult-on-the-Pitt. It was sad to think that this is the last that is left in this country of the name of one who up to his death was a very good and true friend, but it is pleasant to say that now at least the place that bears the famous French electrometallurgist's name has become prosperous. The Noble Electric Steel Company has had a hard time in an up-hill fight.

When Mr. H. H. Noble, as president of the Northern California Power Company, with true pioneer spirit conceived the idea of introducing electric iron reduction and steel refining to the Pacific Coast, he had be-

NORTH FORK FEATHER RIVER, CAPABLE OF PRODUCING 600,000 HP.

sides cheap power ($12 per horsepower-year) one very big asset—a really magnificent iron ore and limestone mine. This mine is still the biggest asset of the company.

The plant was started by Dr. Paul Heroult, who was assisted by Mr. N. Petinot, and pig iron was successfully made. Then came a series of administrations, each characterized by a new furnace design. They were all carefully worked-out designs, but they all proved commercial failures. Each of these furnaces was worked for a time and subjected to improvements, but had finally to be abandoned. Most of the furnaces are still there, and the part of the plant where they are is something like a furnace museum.

If at this late date we may venture a reason for this succession of failures, we believe we are right in saying that everyone of the different furnace designers tried too much and wanted to make efficiency a maximum at once. It was overlooked that the first aim must be to make the furnace work in continuous foolproof operation, and that when this is accomplished there will be time to look after finesses in the saving of heat units and other improvements. In trying to make a furnace theoretically perfect from the start, one is liable to introduce mechanical complications which will be fatal in operation.

It is to the great credit of the present manager of the Noble Electric Steel Company, Dr. W. W. Clark, to have recognized this fundamental principle, and to have made a complete success of the plant. Since he started operation of the first furnace on April 15, 1916, for making ferromanganese, it has been in continuous operation. Mostly ferromanganese has been made, but when there occurred a lack of supply of manganese ore, the furnace was switched over for the time being to pig iron making. Other ferroalloys have also been made, and it is the intention to go into ferrochrome manufacture, since it is recognized that ferromanganese made in the electric furnace is a war baby. It is also intended to make special steels.

The electric furnace now used is of utmost simplicity of design. In this respect Dr. Clark has gone back to the principle of Dr. Heroult, "simplicity first." It looks as though Dr. Clark is going to make a reputation for himself as a first-class operating man at Heroult-on-the-Pitt, and Mr. Noble deserves our hearty congratulations on the final success of his pioneer work.

A delightful automobile ride over the Cascade Mountains to Redding concluded an ideally perfect day.

A New Industrial Center of Growing Importance on San Francisco Bay

The chief trouble with San Francisco as an industrial center has been in the past the labor problem—the domination of the labor unions. (During our present visit it was the union of waiters and chefs of the many restaurants that were on strike, and on entering Tait's or Techau's we were told by red-ribboned gentlemen and ladies that no fair-minded man should patronize a place unfair to organized labor.) But the labor problem must be solved if San Francisco is to come to what is due to her as a manufacturing city in view of the many obvious very great positional advantages.

San Francisco Bay is already an industrial district of no small importance, and its importance is rapidly increasing. One of the best locations is Pittsburg, at the outlet of the Sacramento and San Joaquin Rivers into San Francisco Bay. It has tidewater transportation, besides three railroads, and it has fresh water supply from the two rivers. It is there that the new plant of the Great Western Electrochemical Company is located about which more will be said later, also the works of the Henry Cowell Lime & Cement Company. Then if we pass along the shore of San Francisco Bay, there are the General Chemical Company of California, the A. L. Smith Lumber Company, the Columbia Steel Company, the refineries of the Union Oil Company, Shell Oil Company and Arroc Oil Company, the Selby Smelter and the Mountain Copper Company, the Hawaii Sugar Company, the Giant Powder Company, the Hercules Powder Company, the Standard Oil Company (having here the largest single oil refinery in the world), and the Stauffer Chemical Company.

This is quite an impressive list as it stands. It shows that the positional advantages of the district are clearly recognized. If we add that in the near future considerably more electric power will be available on tidewater for which there will be no use for lighting, traction and domestic purposes, because the present supply for these purposes is sufficient, then with an excess of electric power available at reasonable rates the incentive to go into new manufactures is self-evident.

This brings us to the new power development of the Great Western Power Company.

GREAT WESTERN POWER COMPANY

It has been argued *a priori* (by a distinguished engineer in a report to his very distinguished company) that no permanent hydroelectric power could be had in California on account of its two seasons, the dry season and

POWER PLANT OF GREAT WESTERN POWER CO. AT LAS PLUMAS

the wet season. But this argument completely overlooks the possibility of regulating the flow of the rivers and storing the water in artificial lakes during the wet season and drawing it off during the dry season.

An excellent example is the development of the Great Western Power Company.

The power of the Great Western Power Company is derived from Almanor Lake—an artificial lake with an area of something like 20,000 acres, in the Feather River Canyon district, a three hours' ride by automobile from Keddie on the Western Pacific. This lake now covers what was formerly the "Big Meadows." By building a comparatively short dam in one corner of the valley it was possible to produce this artificial lake.

The present power house of the Great Western Power Company is at Las Plumas on the Feather River. It has a developed capacity of 60,000 kw., which may be increased to 80,000 kw. or 110,000 hp.

The new development, which is now under way, will utilize the same water in another fall near Belden, where a drop of 2000 ft. is available. This will yield 250,000 hp. so that the total will be 360,000 hp. It is hoped that this development will be completed in about a year.

By developing still other falls, the total that could be developed from the same water could be brought up to 600,000 hp. Besides, more water could be made available.

The interesting point is that the same water is made to work here in several plants in succession and moreover that after it has been used repeatedly for power development, it is finally used for irrigation in the Sacramento Valley where a 100-ft. irrigation canal has been built for watering rice fields; this will form eventually a transportation canal from the Sacramento River to Oroville. In view of this situation it might almost be said that the name Great Western Power Company is a misnomer in so far as it is a water company rather than a power company.

The Great Western Power Company has a splendid organization. At its head is Mr. Mortimer Fleishhacker, who is also president of the Angelo-California Trust Co. and of the Great Western Electrochemical Co.—one of California's ablest constructive financiers. Mr. E. W. Beardsley is general superintendent and Mr. W. W. Briggs general sales agent. Mr. J. M. Howells, the hydraulic engineer of the company, is also the father of the company in that he discovered the possibility of creating the lake and built the dam. Mr. J. W. Beckman

BIG MEADOWS DAM FORMING LAKE ALMANOR, SHOWING SPILLWAY AND OUTLET TUNNEL, NEXT LARGEST ARTIFICIAL LAKE IN THE WORLD

GREAT WESTERN ELECTROCHEMICAL CO., PITTSBURGH, CAL.

is the chemical engineer of the company looking for uses of power in electrochemical plants. Thus Mr. Howells and Mr. Beckman may be called the pioneers of the head and the tail of the company.

To Mr. Beckman we are indebted for some unforgetable delightful days along the Feather River with a grand auto trip from Keddie to Almanor Lake and over to the Belden Trail (Yellow Creek trail) where the new 2000-ft. fall is to be developed. Our thanks for courtesies received are also due to Mr. Roberts in charge at Almanor Lake and to Mr. Cane and Mr. Menzel in charge at the power house in Las Plumas.

GREAT WESTERN ELECTROCHEMICAL COMPANY

The Great Western Electrochemical Company is an outcome of the conviction that if all the power which can be made available by the Great Western Power Company is to be utilized an outlet must be found in electrochemical industries. Mr. Mortimer Fleishhacker is the president; Mr. John F. Bush (formerly general manager of the Hooker Electrochemical Company) is vice-president and general manager; Mr. J. W. Beckman is chemical engineer.

Ground was broken for the new plant at Pittsburgh on San Francisco Bay in February, 1916, and operation was started in the latter part of July for the production of caustic soda and chlorine by electrolysis of brine. The capacity is 2500 hp., the output 5000 tons of caustic soda and 10,000 tons of bleach. Experiments are under way for the manufacture of other chlorine products. Power is obtained from the Great Western Power Company at very reasonable rate.

The Moore Allen cell is employed. This is a diaphragm cell used by the Jessup & Moore Paper Company; it is very similar to the Townsend cell, but no oil is used.

The bleach made is sold principally for paper bleaching in the Pacific Coast States and in Canada, but as an indication of the peculiarities of the present time it may be said that some of the bleach has been sold to Sweden and Norway.

The caustic soda is sold chiefly to plants at San Francisco Bay, part of it in liquid form.

Messrs. Bush, Beach & Gent are the sales agents of the company. While caustic soda and chlorine are the first products of the company, the intention is to enter other electrochemical industries. Mr. Beckman has a vision as to the electrochemical possibilities of the Pacific Coast and he is strongly backed by the industrial and financial genius of Mr. Fleishhacker. The develop-

ment of the company deserves close and friendly attention.

OTHER NEW DEVELOPMENTS AT SAN FRANCISCO

At Oakland, across the Bay, the Electro Alkaline Company has been operating for some time a small plant of twelve Whiting cells for the production of hypochlorite. With present prices the business is highly profitable.

In Visitation Valley, San Francisco, the Rankin process for fixation of atmospheric nitrogen is tried out in a 1000-kw. furnace, after experiments in a smaller furnace had been made in Nevada. No definite results can yet be announced. Mr. E. B. Bumsted, a civil engineer of San Francisco and the present president of the San Francisco Engineers Club, is backing the venture.

At the Berkeley station of the Bureau of Mines under Dr. Duschak much attention is paid at present to the cause of explosions which have occurred recently and repeatedly in oxy-acetylene welding plants along the Coast.

Mr. E. J. Fowler of the Pacific Foundry Company has made a great success with his non-corrosive "corrosiron," while from Mr. E. L. Oliver of the Oliver Continuous Filter Company, we learn that his filter is entering the chemical field.

The chemical industries are moving in California, and it is a pleasure to watch them. Even a hurried business trip, with some things to worry about (not the least being the threatening railroad strike), is a source of continuous delight in sun-kissed California.

(A second article on Southern California developments will follow.)

Exhibitors at Chemical Exposition

In the following we give an alphabetical list, complete up to Sept. 13, of the exhibitors at the Second National Exposition of Chemical Industries, to be held in the Grand Central Palace, New York City, in the week of Sept. 25, 1916.

Abbe Engineering Co.; Abbe, Paul O.; Alberene Stone Co.; American Chemical Society; American Coal & By-Product Coke Co.; American Electrochemical Society; American Institute of Mining Engineers; American Synthetic Dyes, Ltd.; American Transformer Co.; American Synthetic Color Co., Inc.; Angel & Co., H. Reeve; Arnold, Hoffman & Co.

Badger & Sons Co., E. B.; Baker, J. T., Chemical Co.; Barber Asphalt Paving Co.; Barrett Company, The; Bausch & Lomb Optical Co.; Beckers, W., Aniline & Chemical Works; Beighley Electric Co.; Benzol Products Co.; Bethlehem Foundry & Machine Co.; Bristol Co., The; Brown Instrument Co.; Buffalo Foundry & Machine Co.; Butterworth-Judson Corporation.

Carborundum Co.; Carrier Engineering Corporation; Castner Electrolytic Alkali Works; Carolina, Clinchfield & Ohio Ry.; Celluloid Zapon Co.; Central Foundry Co., The; Chadwick-Boston Lead Co.; Chemical Catalog Co.; Chemical Co. of America; Chemists' Club, The; Coatesville Boiler Works; Codd Co., E. J.; Condensite Co. of America; Contact Process Co.; Corn Products Refining Co.; Corning Glass Works.

Day Co., J. H.; De Laval Separator Co.; Denver Fire Clay Co.; Detroit Range Boiler Co.; Devine Co., J. P.; Dorr Company; Dow Chemical Co.; Downington Mfg. Co.; Driver-Harris Wire Co.; DuPont, E. I., DeNemours Co.; Duriron Castings Co.

Edison, Thos. A.; Eimer & Amend; Electro Bleaching Gas Co.; Electrochemical Co., The; Electron Chemical Co.; Electrolytic Zinc Co., Inc.; Elyria Enameled Products Co.

Fabra Co., Ltd., The; Foote Mineral Co.; Foxboro Co., The; Franco-Swiss Colours Co.; Freeport Sulphur Co.; Fuller Engineering Co.

Geissinger Regulator Co.; General Bakelite Co.; General Chemical Co.; General Electric Co.; German-American Stoneware Works; Glens Falls Machine Works; Golden Chest Mine; Great Western Power Co.; Great Western Silica Co.; Greiner Co., Emil, The.

Hardinge-Conical Mill Co.; Harrison Bros. & Co.; Hemingway, Frank, Corporation; Hayward & Co., S. F.; Herold China & Pottery Co., The; Holz, Herman A.; Hooker Electrochemical Co.; Huff Elecctrostatic Sep. Co.; Huyck & Sons, F. C.

Industrial Filtration Corporation; Industrial Research Co.; International Equipment Co.; International Glass Co.

Kieselguhr Co. of America; Kleinschmidt & Co., F.; Koppers Co., H.; Koven & Bro., L. O.

Laboratory Supply Co., The; Lead Lined Iron Pipe Co.; Leeds & Northrup Co., The; Lehigh Car, Wheel & Axle Works; Lehigh Foundry Co.; Lehigh Stoker Co.; Lenz & Naumann, Inc. (American Apparatus Corporation); Life Saving Devices Co.; Little, Arthur D., Inc., Boston; Lungwitz, Emil E.; Luzerne Rubber Co.

Madero Bros.; Manufacturers' Record; Marden, Orth & Hastings Co.; Merck & Co.; Metals Disintegrating Co., The; Metallurgical & Chemical Engineering; Mathieson Alkali Works; Mine & Smelter Supply Co.; Mississippi River Power Co.; Monsanto Chemical Works; Mott, J. L., Iron Works; Multi-Metal Sep. Screen Co.

Nash Engineering Co.; National Aniline & Chemical Co.; National Gum & Mica Co.; Newark Department of Docks and Meadows; Newport Hydro-Carbon Co.; Niagara Alkali Co.; Nitrogen Products Co.; Norton Co.

Ohio Pottery Co.

Palo Company, The; Paper, Inc.; Paper Trade Journal; Patterson-Allen Engineering Co.; Pennsylvania Salt Mfg. Co.; Pfaudler Co., The; Precision Instrument Co.; Process Engineers, Ltd.; Product Sales Co., The; Prest-O-Lite Co., Inc., The; Pyrolectric Instrument Co.

Raritan Copper Works; Raymond Bros. Impact Pulverizer Co.; Research Corporation; Roessler & Hasslacher Chem. Co.; Ruggles-Coles Engineering Co.

Schaeffer & Budenberg Mfg. Co.; Schaum & Uhlinger, Inc.; Schutte & Koerting Co.; Scott & Co., Ernest; Scientific Materials Co.; Semet-Solvay Co.; Seydel Mfg. Co.; Sharples Specialty Co.; Shriver & Co., T.; Sidio Co. of America, The; Society of Chemical Industry; Solvay Process Co., The; Sowers Mfg. Co.; Squibb & Sons, E. R.; Stamford Mfg. Co.; Standard Aniline Products, Inc.; Stevens-Aylsworth Co.; Stone & Webster Eng. Corp.; Stuart & Peterson Co., The; Sturtevant Mill Co.; Sweetland Filter Press Co.; Swenson Evaporator Co.; Swiss Colours Co., Inc.

Takamine Laboratory; Taylor Instrument Companies; Technical Association of Paper & Pulp Industry; Tennessee Power Co.; Tennessee Coal, Iron & Railroad Co.; Textile Colorist; Thermal Syndicate, Ltd., The; Thwing Instrument Co.; Toch Bros.; Tolhurst Machine Works.

Uehling Instrument Co.; Union Sulphur Co.; United Gas Improvement Co.; United Lead Co. (Chadwick Boston Lead Co.); United States Bureau of Mines; United States Cast Iron Pipe & Foundry Co.; United States Bureau of Standards; United States Smelting Co.; Universal Fibre Co., Inc.

Valley Iron Works.

Weiller Mfg. Co.; Werner & Pfleiderer Co.; West Pulverizing Mach. Co.; Westinghouse Elec & Mfg. Co.; Whitall Tatum Co.; Williamsburg Chemical Co., Inc.

Zapon Leather Cloth Co.; Zaremba Co.

Chilean Nitrate Statistics for July

Chile's production and exportation of nitrate during July were both on a large scale according to *Commerce Reports*. There were produced in all the oficinas 5,312,776 Spanish quintals (of 101.4 lb. each) and the exports amounted to 5,674,088 quintals.

The market at Valparaiso, where almost all the transactions in the sale and resale of nitrate take place, was not very active during the month, and the change in price was slight. At the end of the month ordinary, or 95 per cent, nitrate was quoted for sale at about 7s. 5d. ($1.80) per quintal alongside for delivery in the latter part of 1916. Nitrate for delivery in 1917 is held about a penny ($0.02) higher per quintal. Refined nitrate, 96 per cent—1 per cent, sold as high as 7s. 10d. ($1.90) per quintal, but for 1917 delivery concessions from this price down to about 7s. 8d. ($1.87) were spoken of.

The Processes of the Organic Chemical Industry Used in the Manufacture of Intermediate Products

BY A. H. NEY AND D. J. VAN MARLE

There are six raw materials, derived from coal-tar or obtained in the by-product recovery of the coke-oven industry, from which the large number of the intermediate products are obtained. These six products are benzol, toluol, xylol, naphthalene, anthracene and phenol.

By submitting these raw materials to the action of different chemicals in succession, it is possible to obtain from one raw material different intermediate products. By changing the order in which we let these chemicals act, or by changing the proportions or physical conditions (especially the temperature), we are able to obtain different intermediate products with the same chemicals from the same raw materials.

The nature of the operation depends on the chemical we use, so that the action of one chemical on different products is very similar from a mechanical standpoint, and the apparatus in which the operation is carried out is essentially the same.

The most important operations are:

Nitration, carried out by means of nitrating or mixed acid, a mixture of nitric and sulfuric acid, by which the material acted upon is converted into a nitro-compound, and often followed by a reduction, transforming the nitro-compound into an amido-compound by the action of iron and hydrochloric acid.

Sulfonation, carried out by means of sulfuric acid of different concentration, by which sulfonic acids are formed, which are often converted into hydroxyl compounds by a caustic fusion, viz., by fusing with caustic soda in open kettles or in autoclaves under pressure.

Due to the chemical constitution of the products, often different products are formed in one operation. In the benzol-, toluol-, and xylol-series we distinguish these products as ortho-, meta-, and para-compounds, and as a rule either the meta- or the ortho-, and para-compounds are formed almost exclusively. From naphthalene two different products can be formed, the alpha- and beta-compounds. When more than one chemical agent acts on one of the raw materials, the situation becomes more complicated, and in most cases a mixture of different products is formed, which has to be separated. The anthracene compounds form a class by themselves, as the product obtained therefrom are dyes themselves, and they will therefore not be taken into consideration. The derivatives of phenol mostly are not prepared from phenol, but from compounds of the benzol-series, so that the whole field can be divided into two parts, the benzol- and the naphthalene-compounds.

A few examples will illustrate what has been said, and show how it is possible to obtain many intermediate products from these few raw materials.

By nitration of benzol nitrobenzol is formed, but by using the double amount of nitrating acid, the nitration can be carried further, and we obtain meta-dinitrobenzol, which contains two nitro-groups. By reduction of nitrobenzol, it is converted into aniline. Reducing meta-dinitro-benzol, however, we can prepare two products by reducing one nitro-group or both, which is possible by the use of a different reducing agent. With sodium sulfide only one nitro-group is reduced, and meta-nitraniline is formed; with iron both nitro-groups are reduced, converting meta-dinitro-benzol into meta-phenylene-diamine.

To prepare the respective para-compounds, para-nitraniline and para-phenylenediamine, we have to start from aniline, which first is converted into acetanilide by means of glacial acetic acid, then nitrated. The nitro-compound on saponification yields para-nitraniline, and after reduction para-phenylenediamine. A small amount of the ortho-compound is formed during the nitration, the less the lower the temperature is kept.

That the order in which the chemicals act can have a decided influence on the product formed can be shown by the action of chlorine gas on benzol, forming chlorbenzol, which by nitration is converted into a mixture of ortho-and para-nitro-chlorbenzol. Nitrating benzol first, and chlorinating the nitrobenzol, we obtain meta-nitro-chlorbenzol.

In the naphthalene series the temperature is the deciding factor on the nature of the product formed, as by sulfonating naphthalene both alpha- and beta-naphthalene-sulfonic acid are formed, the latter mostly at high temperature, the former at low temperature.

By caustic fusion we can obtain the alpha- and beta-naphthol, the latter operation only being carried out commercially. Sulfonating beta-naphthol it is theoretically possible to obtain seven different bete-naphthol-sulfonic acids, but only two are formed. By a larger amount of sulfuric acid two disulfonic acids are obtained, and in both cases it depends on the temperature, which one predominates in the mixture.

The classes of compounds members of which are of commercial value are:

Nitro-compounds, containing the NO_2 or nitro-group.

Amido-compounds, containing the NH_2 or amido-group.

Chlorine-compounds, containing the Cl or chlorine group.

Hydroxyl-compounds, containing the OH or hydroxyl group (phenols and naphthols).

Alkyl-compounds, containing the CH_3 or methyl group, or C_2H_5 or ethyl group.

Acetyl-compounds, containing the $COCH_3$ or acetyl group.

Acids-compounds, containing the COOH or carboxyl group.

Sulfonic acids, containing the SO_3H or sulfonic acid group.

Aldehydes and ketones, containing the CO or carbonyl group.

They are generally obtained by the action of nitrating acid (nitration), iron (reduction), chlorine (chlorination), caustic soda (caustic fusion), alcohol or other agents (alkylation), acetic acid (acetylation), carbonic acid (carboxylation), or sulfuric acid (sulfonation) respectively.

These operations we will now discuss more in detail.

Nitration

By the action of nitric acid on organic compounds of the aromatic series, a group of products is formed which are called nitro-compounds. The action of nitric acid consists in the replacement of a hydrogen atom by the NO_2 or nitro-group. In a few cases not a hydrogen-atom but another group, such as the sulfonic acid- or carboxyl-group is replaced. Examples of practical interest being the nitration of the alpha-naphthol sulfonic acids, which are formed by sulfonation of alpha naphthol, and are converted into dinitronaphthol or its sulfonic acid, commercially known as Naphthol Yellow S., and the nitration of phenol-trisulfonic acid, which is converted into picric acid, all three sulfonic acid groups being replaced by nitro-groups.

It is possible to replace more than one hydrogen-atom by a nitro-group, but in most cases not more than three are replaced, in this way forming mono-nitro, dinitro and trinitro compounds. The preparation of mono-

nitro-compounds is comparatively easy, but it is more difficult to make a second or third group enter, and especially in the last case a certain excess of nitric acid is required, and it is necessary to increase the concentration of the acid and to carry the separation out at a higher temperature. Much heat is generated during the reaction, and the reaction, therefore, has to be kept under control by means of artificial cooling.

In the benzol series three different nitro-compounds can be obtained, the ortho-, meta- and para-compounds. It depends on the groups already present in which position the nitro-group enters, and as a rule it enters in meta-position to a nitro-, sulfonic acid, carboxyl- or carbonyl-group, and in ortho- and para-position to a chlorine-, bromine-, alkyl-, amido- and hydroxyl-group. The proportions in which the ortho- and para-compound are found depend to a large extent on the temperature, the para-compound being formed in increasing amount of lower temperature. In case two or more groups are already present, it is hard to predict which compound will be formed owing to conflicting influences of these groups, and often a mixture of different compounds will be the result of this nitration. In most cases a fairly homogeneous product will be formed ,and by-products will only be present to a small extent, so that a nitration is one of the operations which is carried out in the organic chemical industry with the greatest success.

In the naphthalene series two different nitro-compounds can be formed, the alpha- and beta-compound. The nitro-group here enters almost exclusively in alpha-position, a second nitro-group entering in position 5 or 8 to the first. In case any sulfuric acid groups are present, the nitro-group enters by preference in position 3 or 8 to one of these groups.

NITRIC ACID

The form in which the nitric acid is generally used, is as nitrating acid or mixed acid, which is a mixture of nitric and sulfuric acid. During the reaction water is formed, which tends to dilute the acid, and in case straight nitric acid is used the acid would become so dilute that it would be no longer effective, necessitating the use of an excess of nitric acid to complete the reaction, which excess, on the other hand, may cause a small amount of higher nitrated products to be formed, which would cause serious trouble in subsequent operations.

The sulfuric acid present in the mixture will bind the water formed during the reaction, and the nitration can, therefore, generally be carried out with the theoretical amount of nitric acid, which also means a considerable saving, as nitric acid is much more expensive than sulfuric acid, and the waste acid, which contains only a small amount of impurities, can be mostly recovered and used for other purposes. The greatest advantage, however, is that whereas nitric acid has a strongly corroding effect on iron, the action of nitrating acid is only slight, and allows it to be shipped in drums, and to carry the nitration out in cast-iron kettles, which makes it possible to manufacture this class of products on a large scale. The presence of sulfuric acid also makes it easier to keep the reaction under control, and the only disadvantage is that much heat is generated by the water which is formed and the sulfuric acid, which causes a material loss of time, as most nitrations have to be carried out at low temperature.

In certain cases the sulfuric acid determines the place in which the nitro-group enters the molecule, and its presence, therefore, can be objectionable unless a method is adopted to counteract its influence. This can be best illustrated with the example of the nitration of aniline, which gives amido-benzol, and from which two important products are derived, meta- and para-nitraniline. The amido-group directs the nitro-group in para- and to a smaller extent in ortho-position, but as it has basic properties, it forms with the sulfuric acid an acid sulfate, which causes the nitro-group to enter also in meta-position, so that the result of the nitration is a mixture of three products, which would have to be separated. By first converting aniline into acetanilide, its acetyl-compound, by means of acetic acid, it is possible to neutralize its basic properties and prevent the formation of acid sulfate, so that now almost exclusively the para-compound is formed. The meta-compound can be obtained in an entirely different way, as we shall see later.

The nitrating acid, which is generally used, is a mixture of 1 part of nitric acid with 1-2 parts of sulfuric acid, but in a few cases where it is required to use a much more concentrated acid, the nitric acid can be mixed with fuming sulfuric acid, which is cheaper than using a mixture of highly concentrated nitric acid with sulfuric acid.

The nitric acid may be replaced by its salts, such as sodium nitrate, which when mixed with sulfuric acid forms nitric acid and sodium bisulfate, but as this causes mechanical difficulties, it is not often practised, even though it would be cheaper.

There is one class of products, those containing a hydroxyl group, such as phenol and alpha-naphthol, which react very violently with nitric acid and are easily oxidized. Dilute nitric acid already converts them into their nitro-compounds, and the nitration of phenol by means of dilute nitric acid has been carried out on a commercial scale, as the para-compound is used in the manufacture of para-amido-phenol. This process has been abandoned, however, as a much larger amount of the ortho-compound is formed and another way of preparation has been found. The dinitro-naphthol and trinitrophenol or picric acid are of much value, however, and in order to obtain these products, the naphthol and phenol are first converted into the sulfonic acids, the sulfonic acid groups being replaced by the nitro-group and any oxidation being prevented.

TEMPERATURE

In contradistinction to sulfonation, the temperature in nitration has no influence on the nature of the reaction-product, and is only of importance in regard to its purity. In the first place at higher temperature the nitration may be carried further, so that a small amount of a higher nitrated product may be formed, which, as already pointed out, may cause difficulties in subsequent operations. In the second place nitric acid is an oxidizing agent, and especially at high temperature the oxidizing action becomes more pronounced, and part of the material may be converted into products which are entirely valueless, which causes a loss of material and makes purification necessary. The presence of sulfuric acid, which tends to the formation of nitrosyl-sulfuric acid, a compound with strong oxidizing properties, also may cause oxidation, and it is therefore of the greatest importance to keep the temperature sufficiently low to prevent this action, especially when the material to be nitrated is easily oxidized. The oxidation is accompanied by the development of nitrous fumes, which may cause still more complications, in case the material to be nitrated can be reacted upon by nitrous acid. For example, the amido-compound, which may be converted into diazo-compounds and later in the process into hydroxyl-compounds, and the alkylated amido-compound and hydroxyl-compound, which are able to form nitroso-compounds by the action of nitric acid.

For this reason it also is advisable to protect the

amido- and hydroxyl-groups, and the least expensive way is to convert them into their acetyl-compounds by means of acetic acid, which can be easily saponified, in order to obtain the nitro-compounds. Formic acid and for the amido-compounds benazldehyde also may be used for this purpose.

Much heat is generated during the reaction, partially due to the presence of sulfuric acid, and it therefore is necessary to supply the vessels in which the nitration is carried out with a cooling jacket, which serves at the same time as heating jacket, in case it is necessary to raise the temperature at the end in order to complete the reaction.

Last, but not least, the temperature should be kept under control, as at higher temperature the reaction may become too violent, which may cause serious explosions, two of the products of this class, picric acid and trinitrotoluol, obtained by nitration of phenol and toluol respectively, being used in enormous quantities as military explosives.

APPLICATION

The largest application for the nitro-compounds is found as intermediate products in the manufacture of amido-compounds. The simplest and best known member of this series is nitrobenzol, obtained by nitration of benzol, and converted by reduction into aniline. Enormous quantities are yearly produced, the production of aniline in the United States now being 15,000 tons, requiring the production of approximately one and one-half times its weight of nitrobenzol, to which has to be added the large amount used as solvent and for the manufacture of benzidine. Starting from toluol, xylol and naphthalene we obtain the intermediate products for toludine, xylidine and naphthylamine, which are applied to a large extent in the manufacture of many azo-dyes, and themselves again can be converted into other valuable products. The nitration of toluol yields a mixture of the ortho- and para-compound, which can be separated by fractional distillation in vacuum, and freezing out the para-nitrotoluol from the residue. The para-toluidine has a larger value than the ortho-compound, while the para-nitrotoluol-sulfonic acid also is used in the production of the stillbene-dyes. The ortho-nitrotoluol can be converted into tolidine, which in its properties is very similar to benzidine. Commercial xylol is a mixture of ortho-, meta-, and para-xylol, which on nitration forms a mixture of not less than five nitro-xylols, of which the meta-compound is present in the largest amount and also is the most valuable. A separation here is not carried out.

Other nitro-compounds which are further reduced to amido compounds are those of benzol-sulfonic acid, acetanilide, dimethylaniline, benzoic acid, salicylic acid and benzaldehyde, used for the manufacture of metanilic acid, para-phenylene-diamine, dimethyl-meta-phenylene-diamine, amido-benzoic acid, amido-salicylic acid and amido-benzaldehyde respectively. Nitro-benzaldehyde itself is also used in the preparation of certain dyes of the triphenylenethane series.

On further nitration dinitro-compounds are formed, the most important being dinitrobenzol and dinitrotoluol, in the last case the ortho- and para-nitrotoluol both being converted into the 2-4 dinitro-toluol, the ortho-compound at the same time forming a small amount of the 2-6 dinitro-toluol. Naphtalene on the contrary forms only one mono-nitrocompound, but two dinitro-compounds, the 1-5 and 1-8 dinitronaphtalene, the first to a much smaller extent, but of larger value as it forms by treatment with zinc and concentrated sulfuric acid naphtazarine or alizarine-black, a very fast chrome-black. It has been tried to make use of the 1-8 dinitro-naphtalene by making a sulfur-black from it, which however has not been able to compete with other blacks of this class.

Nitro-compounds are also used in the manufacture of azo-dyes, para-nitraniline, obtained by nitration of acetanilide, followed by saponification, being used in large quantities. When combined with beta-naphthol, para-red is formed. This dye being insoluble it is prepared on the fibre and can also be used in the paint-industry. It is remarkable that when a small amount of one of the beta-naphthol-sulfonic acids is added a much bluer shade can be prepared. The nitro-toluidine derived from para-toluidine also gives a valuable red lake. Para-nitraniline also is used for developing a number of azo-dyes on the fibre, which improves their quality.

Much attention has also been paid to the nitration of chlorbenzol, as the nitro-chlorbenzol by heating with caustic soda forms nitrophenol, which can be reduced to amidophenol. The para-amidophenol is of value as a photographic developer, and important medicinal products, like phenacetine are derived from it. Originally para-nitrophenol could only be made by nitration of phenol, when a much larger amount of ortho-phenol is formed, aside from the fact that the nitration had to be done with dilute nitric acid. The ortho-nitrophenol can be used for making anisidine and dianisidine, but for large quantities no outlet could be found. Dinitrochlorbenzol, when fused with sodium-polysulfide gives one of the best sulfur-blacks, which is now largely produced in the United States. When combined with para-amidophenol or dimethylaniline before fusion it will form a valuable sulfur-blue.

In the naphtalene-series nitrations are of importance for the manufacture of alpha- and naphtylamine-sulfonic

NITRATOR WITH COOLING TUBES—1600-GAL. SIZE

acids and amido-naphthol-sulfonic acids which belong to the most important constituents for many azo-dyes. By nitration of alpha-naphthol and its sulfonic acids nitro-compounds are formed, which themselves are used as dyes, those being known as naphthol yellow. This is the only practical application of a nitro-compound as a dye, others having been superseded by dyes with more desirable properties.

To this class of products also belong two explosives of high value, trinitrotoluol and trinitrophenol or picric acid, of which the high importance at the present time is well known.

APPARATUS

The nitrations are carried out in cast-iron kettles surrounded by a cooling jacket, and provided with an agitator. Even if not entirely necessary, it is preferable to build the kettles of acid-resisting cast iron, which last much longer than those of ordinary cast iron.

As the raw material can be a liquid or a solid, there are two different ways of carrying out the nitration. If it is a liquid the nitrating acid is run into the raw material, in the other case the acid being put in the kettle first, and the material being added gradually. The materials have to be weighed out accurately, a measuring tank placed on a platform scale being provided for this purpose, for the acid and the liquid material.

In most cases neither the raw material nor the nitro-compound mix with the acid, so that to prevent the formation of two layers an efficient agitator, run at high speed, has to be provided, as insufficient agitation will result in an incomplete nitration, and may allow the nitrating acid to accumulate without acting on the material. In this case the nitration may start suddenly and control may be lost of the operation. There are two types of agitators which have given satisfaction, one consisting of a right- and left-handed propeller, the other of a screw conveyor placed inside a cylinder. Nitrators are built up to 1600 gallons capacity, the larger sizes being provided with a series of tubes, suspended from the cover, through which cooling water is circulated, as jacket cooling here would be insufficient. Every tube is operated individually, and can be replaced in case of leakage without interfering with the operation.

According to the nature of the product, there are three ways of separating this from the waste acid. A liquid nitro-compound is separated from the acid in a lead-lined tank with conical bottom, and collected in a storage tank; a nitro-compound of low melting point can be separated from the acid after it has solidified in a flat, lead-lined tank, while a nitro-product of high melting point can best be separated on a suction filter or by means of a centrifugal, if necessary after diluting the nitration-mixture in a lead-lined tank. The waste acid can be recovered, and concentrated or used for other purposes. In all cases the product is washed with water to remove the last parts of acid.

A number of products like dimethylaniline and acetanilide are dissolved in sulfuric acid before nitration. In this case as in that of the sulfonic acids, where the sulfonation mixture is directly nitrated, the nitration mixture is a homogeneous liquid from which the nitro-compound can be obtained by diluting with water in a lead-lined tank, and sometimes by the addition of salt. The nitro-product is filtered off in a wooden filter press or on a suction-filter, according to its nature and washed free of acid.

Most of the nitro-compounds are reduced without purification. In many cases, where it is crystalline, small amounts of impurities, which adhere to it in a liquid form, can be separated in a centrifugal. In a few cases where a purification of the product is necessary, this will depend on the nature of the product and the impurities.

In recent years different patents have been taken out, in which a process for continuous nitration has been described, which would make it possible to nitrate large quantities of material in a small inexpensive apparatus. The only product for which this process would be of interest would be nitrobenzol, as others are not produced in sufficiently large quantities. The apparatus consists of four small jacketed nitrators with high-speed agitators. The first and second ones are cooled, the last one is heated. The benzol and nitrating acid are introduced simultaneonsly in the first kettle in the correct proportions. The kettle is connected to the next one by a siphon, which is arranged in such a way that when the mixture reaches a certain level, it is gradually withdrawn at the bottom and flows into the second kettle, then into the third and the fourth, from which it runs into a separating tank. If this interesting process has found application on a large scale is not known.

Conventions of American Foundrymen's Association and American Institute of Metals

This is foundrymen's week at Cleveland, Ohio. Both the American Foundrymen's Association and the American Institute of Metals are holding their annual contions, and under their joint auspices there is a big exhibition of foundry equipment, supplies, machine tools and accessories.

The programs of the technical sessions are very full. One session per day is held by either association. Among the papers there is a symposium on the results of closer co-operation between the engineer and the foundry, another one on the influence of gating on castings, another one on electric furnace practice. Some of the papers presented before the Institute of Metals are printed elsewhere in this issue.

Among the exhibitors may be mentioned the Armstrong Cork Company of Pittsburgh, Pa.; the Beighlee Electric Company, Cleveland; Brown Hoisting Machinery Company, Cleveland; Carborundum Company, Niagara Falls, N. Y; Charles J. Clark, Chicago; Cleveland Blow Pipe & Manufacturing Company, Cleveland; Davis, Bournonville Company, Jersey City, N. J.; Joseph Dixon Crucible Company, Jersey City, N. J.; General Electric Company, Schenectady, N. Y.; Gisholt Machine Company, Madison, Wis.; Goldschmidt Thermit Company, New York; Hauck Manufacturing Company, Brooklyn, N. Y.; Herman A. Holz, New York; Imperial Brass Manufacturing Company, Chicago; Julius King Optical Company, New York; Lakewood Engineering Company, Cleveland; H. M. Lane, Detroit; Life Saving Devices Company, Chicago; Lincoln Electric Company, Cleveland; Monarch Engineering & Manufacturing Company, Baltimore; Multi-Metal Separating Screen Company, New York; Norton Company, Worcester, Mass.; Pangborn Corporation, Hagerstown, Md.; Prest-O-Lite Company, Indianapolis; Pyrotectite Company, Chicago; Robeson Process Company, New York; Searchlight Company, Chicago; Sullivan Machinery Company, Chicago; Titanium Alloy Manufacturing Company, Niagara Falls, N. Y.; Union Steam Pump Company, Battle Creek, Mich.

Among the entertainment features will be a trip to a ball game Tuesday afternoon, a theater party Tuesday evening, an inspection trip to the Cleveland Blast Furnace Co.'s plant on Wednesday, and other trips.

Design of Factories for the Manufacture of Dyestuffs

By Percival Robert Moses, E. E.

President of Moses, Pope & Messer, Inc.

The great war, imposing as it did a practical prohibition of imports of dyes into this country, has caused a rapid development of the dye industry, but there seems to be a general lack of appreciation of the fundamental facts in connection with the design of plants for this industry, due to a lack of knowledge of the special problems to be met and solved, and as many of these problems have come before us in the design of such factories, an article on the subject of the design of factories for manufacturing dyes and chemicals appears to be timely, and probably useful to those contemplating building.

It goes without saying that under the existing conditions, with a famine existing and with dyes commanding prices more than 1000 per cent higher than the prices before the war, almost any kind of a plant, operated in almost any kind of manner should be able to make money, provided sufficient capital is available to tide over the period of making and correcting mistakes, but after the existing conditions cease the plants which have not observed the fundamental requirements for efficient manufacture will undoubtedly go to the wall.

GENERAL PROCESS

The general process of dye manufacture involves the mixing and heating of liquids, or liquids and gases or liquids and solids; the evaporation, crystallization and distillation of the resulting solutions, accompanied by filtering, drying and grinding in order to produce the finished product. The materials used are largely the products of the distillation of the light oils contained in gas or in tar, such as benzol, toluol, xylol, phenol, naphthaline, anthracene and solvent naphtha. From these are made a host of intermediates, such as beta-naphthol, alpha-naphthylamine, anilin oil, and alizarine. These intermediates and the final dyes are formed by sulfonating with sulphuric acid, chlorinating by dry chlorine gas, nitrating with nitric or mixed acids. Acetic acid and hydrochloric acid are also used in connection with iron filings and zinc dust for reducing the nitrated bodies. Large quantities of caustic soda and caustic potash, when this is available, are used for melting the salt formed and removing the sulphuric acid. Lime, soda and occasionally potash are used for changing insoluble into soluble salts, and for neutralizing free acid.

In general, the process is one resulting in the formation of vapors and fumes, and as these are frequently extremely corrosive and in some cases explosive, and in still other cases dangerous to life, the problem of transferring liquids and holding these liquids in storage during the processes and preventing the vapors from escaping into the room or into the atmosphere in an objectionable state is one which has given rise to an immense amount of trouble, most of which could have been avoided with proper knowledge of chemical properties and substances and the material used to hold and convey them.

The same conditions make the problem of fire prevention of special moment. Hardly a week goes by without news of some chemical plant exploding or burning up. This problem can best be met by separate buildings for all processes requiring open fire and isolation of all processes using explosive or easily ignited materials, such as benzol, alcohol and gasoline.

Besides these special requirements, the nature of the processes result in chemical reactions which frequently develop heat, in which case it is necessary to cool the solutions by cold water or in many cases by artificial refrigeration, and in some particular process artificial refrigeration is not sufficient, and ice must be made and used to get the benefit of the absorption of heat due to the latent heat freed in the melting of ice.

The proper and economical heating of the liquids lends itself to the development of the highest efficiency in the utilization of the energy in fuel. Heat is required in three degrees—if the term may be used—high, medium and low temperature heating. For example, in the sulfonation of one of the intermediates a temperature of around 350 deg. C. is required. This can only be obtained—as the product is inflammable—by the use of a highly heated circulating medium in the jacket, surrounding the kettle, such as oil or superheated steam. For this temperature nothing but direct fire will suffice to heat the circulating medium, or waste gases from other sources.

Moderate temperatures, however, are used to a large degree for distillation, boiling and evaporating. This can best be obtained by the use of exhaust steam from the power plant, which may be operated at a sufficient back pressure to give the desired temperature. In one of the plants we recently completed, turbines were installed and operated at a back pressure of 15 lb. per square inch and an initial pressure of 140 lb. The turbine, of course, used a very large amount of steam per kilowatt hour output, but as all the exhaust steam was afterward used for evaporating purposes the turbine acted merely as a reducing valve between the boilers and heating service, and the power was obtained substantially as a by-product of the supply of heat for the evaporating processes.

Low-temperature heating, such as heating of the building, heating of water—large quantities of hot water being required in the processes—can also be best furnished by the use of exhaust steam, the plan adopted varying in different instances, depending on conditions; for example, one of the power units may be arranged to exhaust at the lower back pressure required by the low temperature heating, or if there is only one power unit in operation, the lower pressure exhaust may be obtained from the lower stage of the steam turbine, or the 15-lb. back pressure line may be provided with an automatically controlled release into the lower back pressure line.

The condensation from the coils is returned to the boilers, or if there is danger of contamination a heat exchange may be effected by the outgoing condensation and the cold water on its way to the hot water heating tanks.

Reference has already been made to the need of refrigerating plants, and in the large dye plants these are of great importance, running up into the hundreds of tons capacity. Such refrigerating plants, and the condensation of the vapors in multiple effect evaporators and the reflux condensers require large quantities of water suitable for condensing purposes. It is, therefore, an essential requirement in the choice for a site for the plant that abundant water be available for condensing purposes. The water to be of such character as will not cause undue corrosion to the condenser, or scaling.

Abundant water, but not necessarily of the same character is required for the solutions, for boiler feeding and for washing filter presses and filtering apparatus. Compressed air is also necessary. It is used for blowing the acids from the tank cars into the storage tanks, and from these to the various measuring tanks, also for lifting liquids by means of montejus, and for blowing out filter presses, for agitating, and if oil is used as fuel, compressed air is used for atomizing the oil.

The plan of a dye plant is, therefore, very complex, as it contains all the apparatus required in the ordinary manufacturing establishment with the addition of refrigerating machinery, and elaborate ventilating systems. The materials used must be carefully selected to withstand the liquids and gases to which they are subjected, and the matter of fire prevention, as has been mentioned, is one of greatest importance and of considerable difficulty.

There is another question which is of vital importance in connection with the success or failure of the plant. A very large proportion of raw materials as compared with finished product is required in almost all these operations. For example, in the production of beta naphthol or phenol, approximately 16 tons of raw material, if the coal is included, are required for the production of one ton of finished product.

This condition carries with it several important sequences. The first is that the location of the plant under competitive conditions will spell success or failure, other things being equal. An advance in freight rates of 10 cents per 100 lb. is equivalent to from 1 to 2 cents a pound on the finished product, and on materials which are sold in great bulk, such as sulphur black and the intermediates this sum may represent the entire profit on the sale.

It is essential, therefore, that the plant shall be located so as to enable it to obtain its raw materials at the lowest possible cost, and for this reason a location on the water front where the freight rates are kept down by competition with water shipments, is essential, unless it is possible with some particular type of dye to locate close to a plant producing the greater part of the raw material required, in which case a saving on the freight rate on one material may make up for the higher freight rates on the other materials purchased. But the question of freight rates is one which should be considered and studied with the utmost care.

The second sequence is that the handling of all this raw material must be done with the minimum of labor. This means automatic handling of the coal and ashes, large storage tanks with compressed air for delivering acids and other raw materials (liquids) and in some cases pumps must be used to avoid danger of explosion. The material in transit should be handled by conveyors wherever possible or pumped, and provision should be made for the discharge of some waste products and the storage of others, pending the development of by-products from them.

This question of delivery of the products in transit from one part of the process to another is also one which involves problems not usually met in the ordinary manufacturing plant. The materials in transit are frequently materials which would tend to clog up the pipes or channels, and in such cases the size of pipes must be made large enough to minimize the difficulty, and clean-outs must be provided at every turn of the pipe, and space left for easily getting at these clean-outs.

In other cases materials tend to solidify (or freeze) in transit, and in these instances several methods are adopted depending on the nature of the materials, as for example, surrounding of the pipe carrying the material with a steam jacket, or where this is not necessary, with insulating covering, or in some cases by the injection of steam.

Many of the liquids carried are extremely corrosive, and this difficulty can only be met by choosing the type of material which is least subject to corrosion, as for example the use of lead pipe for weak sulphuric acid, iron pipe for fuming acid, silver or tin or enamelled lined receptacles for acetic acid; earthenware, glass and special acid-resisting irons have all their special advantages and disadvantages which must be considered in determining the best solution for this part of the problem.

BUILDINGS

Building construction will depend upon local conditions, *i.e.*, the comparative cost of brick or concrete or brick and concrete and steel. For many of the processes, mill construction may be used, but generally speaking wooden construction should be avoided, and as between the other types of construction—the less exposed steel work the better, because of the corrosive action of the fumes of sulphuric acid and hydrochloric acid.

Where alkali fumes are present to any extent, wooden construction should also be avoided, so that on the whole a brick structure with possibly a reinforced concrete skeleton if cost conditions make this possible is the most satisfactory.

Such a building can be put up in New York for from 6 cents to 10 cents per cubic foot, which is equivalent to from $1.80 to $3.00 per square foot as the average height of such buildings will be about 30 ft.

The buildings are usually single-storied, part of them being high and part low, the high parts being used to accommodate the many-storied platforms necessary to permit gravity operation.

The other requirements of the buildings are little if any different from the ordinary factory construction. Good light is advisable but not as necessary nor advisable as it is in textile or similar mills. In fact, it is as well from a fire standpoint not to have any more glass than is necessary for the proper carrying on of the operations and in some chemical operations too much light is objectionable.

Ventilation is of the utmost importance, and besides the special ventilation required for the processes such as the liming, nitrating, dissolving in acid, and similar operations, good general ventilation must be provided. Many of the fumes are poisonous, and of course these may be led directly away and not allowed to mix with the general atmosphere. A great deal of vapor is evolved and wherever possible it is collected directly at the apparatus such as the liming tub and led through ducts out into the open air, but in many cases this is not possible. For this reason, good general ventilation is essential.

Where the processes of evaporation and crystallization are carried on in open pans it is frequently essential to prevent any dropping back of condensation from the roof or hood, as this may carry with it impurities sufficient to discolor the whole solution. This is particularly the case if any iron work is exposed.

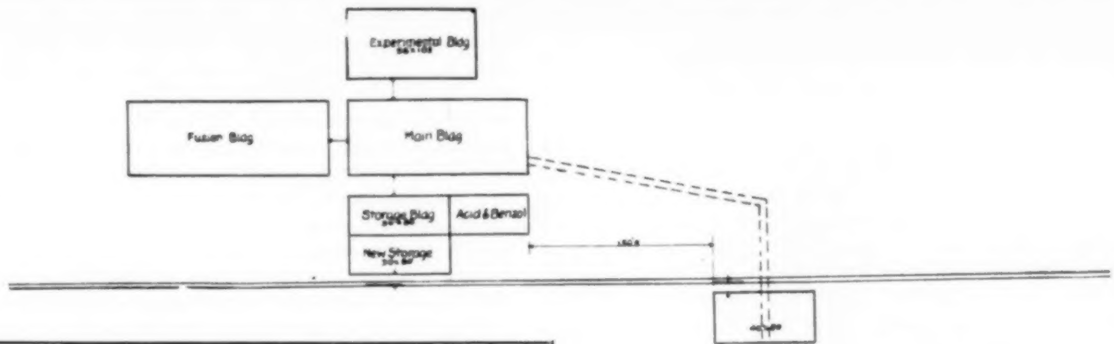
PIPING

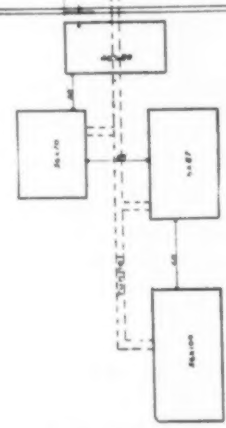
As every dye or chemical factory is liable to change from one product to another according to market conditions, it is usual to arrange the piping in stacks or headers with additional outlets provided at frequent intervals by means of plugged tees or elbows. These groups or stacks of piping include cold and hot water, waste, high, moderate and low (exhaust) pressure steam, condensation returns, compressed air and gas. Acids, benzol, toluol, etc., are usually piped directly to the apparatus supplied unless there are several kettles performing the same operations, in which case headers are run.

Each material requires a particular kind of piping, as already noted in the general discussion.

APPARATUS

The same requirements as to choice of material in piping apply to apparatus. Standard apparatus for the





ARRANGEMENT OF BUILDINGS

various processes are gradually being evolved but as the work other than the tubs and tanks consists mainly of casting and sheet metal work, we have found it better to design each piece of apparatus, such as sulfonators, nitrators or reducers, making the sizes, outlets and supporting arrangements comply with the specific needs of the plant.

Of course, we have adopted general designs for these pieces, and as far as possible these comply with the standard patterns of the manufacturers, but as most of the work is in the stage of evolution in many processes, there are no standards and new apparatus has to be developed from a basis of knowledge of processes of a similar character and information of the materials to be distilled or otherwise treated.

In all this work knowledge of chemistry is essential and the designing engineer should have with him a chemist to inform him of the probable reactions and the chemical effects occurring at each stage, including in chemical effects not only the gases, liquid or solid evolved but the heat developed and the temperature required to be maintained.

Questions of agitation are also important, as the profit on any product will depend under competitive conditions, other things being equal, on the percentage of yield, and this in turn will hang in many operations on the completeness of the mixture and the maintenance of correct temperatures during the process. This question of yields is most important and is the one most frequently forgotten in lay discussions. Almost any good organic chemist can produce a product, but unless the yield approximates the yield obtained by others, the process may be considered a failure.

While a great deal of delay, difficulty and loss has been occasioned by insufficient knowledge, poor workmanship and undue haste on the part of manufacturers of apparatus, the good ones are gradually becoming known and with the wider development of the industry keen competition will not only reduce the present abnormally high prices, but it will result in much better product.

Even under existing rush "war order" conditions, carrying with them labor unrest and hurried work, it is possible by careful inspection and selection to secure reasonable safety in the purchase of apparatus.

ELECTRICAL WORK

Many of the vapors affect insulating materials, and where wiring is exposed to destructive fumes it should be lead-coated. Otherwise the standard rubber and double braid insulated wire is satisfactory if enclosed in conduits, which, however, should be thoroughly protected by painting with suitable paint, such as "P & B" or asphalt paint, particularly at the couplings and outlet boxes.

Alternating-current motors of the brushless type are necessary where inflammable vapors exist, and as these usually exist in some part of the plant, alternating-current is universally adopted. Motors must be of the squirrel-cage induction type wherever inflammable vapors exist or other fumes make it inadvisable to use sliding contacts as required in variable-speed alternating-current motors or in alternating-current motors designed for low starting current. Wherever possible, however, synchronous motors are used to bring up the power factor and over all efficiency. Care must be taken in the location of switch boxes, auto starters and oil-cooled transformers, as with many processes the fumes have chemical effect on the oil and in several cases coming within our own personal experience, motors have burned up and fires have started due to the chemical reaction between the oil and the fumes.

TYPICAL PLANT

The drawing reproduced above shows one of our recent layouts of a chemical plant which is producing two intermediates, with provision for the manufacture of two more in the immediate future.

A brief discussion will perhaps serve to illustrate the points mentioned.

The essential requirements taken care of are that the storage of inflammable materials such as benzol, and alcohol, is kept away from fire hazard, and the departments in which these chemicals are used are kept in entirely distinct buildings from the buildings housing the fusion and distilling operations requiring open flames. The buildings containing the inflammable materials are also kept as far as possible away from danger from locomotive sparks and the construction is essentially fireproof.

Provision is allowed for expansion of the plant by having ample area and by providing space around the buildings so that each building may be added to without interfering with the others.

All the power, steam and compressed air is derived from a central plant which permits of ready expansion of the manufacturing plant and also permits the efficient utilization of all the energy contained in the fuel

by making use of the exhaust steam from the operations of electrical manufacture and the making of compressed air.

Steam is supplied at 150 lb. from the boilers and at 15 lb. from the exhaust of the turbines and at 2 lb. from the other exhausts.

Railroad sidings, storage tanks with capacity for receiving tank-car quantities in addition to the necessary operating reserves together with conveyors and elevators for coal delivery to storage and from storage to the boilers take care of the handling of the raw materials at the minimum cost.

As far as consistent with the separation of the processes requiring flame from those requiring only steam and water, the process is routed on a straight line and where material has to be moved from one building to another because of the separation of processes, the handling of material is done by conveyors and elevators.

For the purpose of economy in handling and also to reduce the cost of piping and avoid stoppages, wherever it is possible to do so, the kettles or filters discharging into tubs are placed directly above the tubs into which they discharge. The measuring tanks which measure the liquids delivered into the kettles are placed above the kettles. This involves in some cases three and four-story platforms, but pumping is avoided with all its manifold objections. Wherever it is necessary to draw from tubs or tanks to discharge through filters or into overhead apparatus, it is our practice to use montejus instead of pumps as montejus require little if any attention. They operate with great rapidity and as they only use power when in operation they are far more efficient than the wasteful steam pump with its continual leakage and its low steam efficiency.

The plant discussed also complies with the requirements mentioned in the beginning of the article, as it is located on the shores of a large body of water which assures an ample supply of good condenser water and pure water for other purposes. The proximity of the plant to the source of supply of benzol, toluol and other raw materials, together with the competition offered by water shipments assures low freight rates for the other raw material not produced near at hand.

The problem of fire protection is solved by the segregation of the buildings, separation by fire spaces and the maintenance of water pressure by elevated tank and chemical fire extinguishers located throughout the plant, together with the usual safeguards required by the insurance companies, such as wire glass windows, fireproof doors, etc.

The location is also a good one from the point of view of labor. The other requirements are also satisfactorily met, viz.: that labor shall be available at reasonable prices and that there shall be comparative freedom from restrictions as to the making of nuisances such as smells caused by the fumes and disposal of waste materials. Two specific instances have come to our knowledge where failure to consider the nuisance question is necessitating the removal of the plants.

COSTS

It is impossible to give any data on costs which will be reliable for any particular process.

The cost of the half dozen plants with which we have had to do, however, runs from $150.00 to $175.00 per ton of finished product per year, exclusive of buildings and from $300.00 to $350.00 a ton including land, buildings, water supply and power plant.

These prices are 1915-1916 prices and are probably higher than those that will obtain when normal conditions recur.

In some of these plants, the process starts from an intermediate such as anilin oil or a crude base such as naphthalene or benzol. In all cases the heavy acids, sulphuric, mixed and acetic were purchased and the products made were the simpler ones having large bulk sales. As these intermediates are themselves used in further processes to produce the finished dyes, it becomes necessary greatly to increase these figures when complex dyes are contemplated, as these involve many sulfonations, nitrations, filterings, washings, reducings, etc., and the recovery processes for the recovery of the various reducing agents and the efficient utilization of waste products are so many separate chemical processes.

The industry has already developed its feeding industries, *i.e.*, the producers of caustic soda by the electrolytic process have added chlorination plants for making the monochlorobenzol used in the making of blacks; coke oven plants have added benzol, toluol and xylol and solvent naphtha recovery plants and are extracting their naphthalene and no doubt will soon be making the other crude bases such as anthracen and alizarine.

The importance of the industry to the United States cannot be measured by the tonnage or value of the dyes or intermediates produced.

The total present needs of this country are estimated at from 35,000 to 40,000 tons a year, but this means that use will be found for three or four hundred thousand tons of sulphuric acid, largely a byproduct of other processes; possibly 100,000 tons of caustic soda; thousands of tons of benzol, toluol, naphthalene, etc., and the production of these quantities of these materials means that the United States will be in a position to supply its own needs for defense if occasion should arise.

All these things are not only possible but they are probable, and observance of basic requirements and efficiency in planning together with protection against different standards of living and unfair competition are all that are needed for the development of a dye industry capable of supplying the needs not only of this country but of a fair share of the world.

The **International Nickel Co.** has acquired additional land at Bayonne, N. J., and will enlarge its plant at a cost of $500,000.

Electric Welding at Electrical Exposition.—Electric welding of iron and steel will be one of the exhibits of the New York Electrical Exposition, which will be held in Grand Central Palace, New York City, Oct. 11 to 21. The exhibit is being arranged by the Arc Welding Machine Company of 220 West Forty-second Street, New York City, and Mr. O. A. Kenyon will be in charge. The public will have an opportunity of seeing all grades of welding accomplished in iron and steel, including structural pieces, plates and castings. Two arcs will be in operation equipped with automatic control so that the metal cannot burn by drawing too long an arc. The length of the arc is automatically controlled so that even the most unskilled worker cannot draw it beyond the point set. A special type of self-regulating generator designed particularly for welding purposes will be used. It consists of three units, one of which supplies the power, another of which regulates for constant current, and a third which takes care of the adjustment. This generator is used exclusively by the Arc Welding Machine Company. The United States Government is co-operating in the Electrical Exposition through the War, Navy and Commerce Departments, all of which will have comprehensive exhibits.

The Selection of a Method of Ore-Treatment

BY GEORGE J. YOUNG

Professor of Metallurgy, Colorado School of Mines

Present Methods of Ore and Mineral Treatment

Methods of ore and mineral treatment are broadly divided into (1) mechanical methods in which the mineral substances retain their identity, and (2) chemical methods in which one or more of the mineral substances are changed into other compounds. Mechanical methods consist of hand-picking, wet concentration, dry concentration, amalgamation, magnetic separation, electrostatic separation and flotation. Chemical methods are divided into smelting methods and those in which a solution of an active chemical agent like potassium cyanide or sulphuric acid is used to dissolve the valuable mineral.

The simplest mechanical methods are hand-picking and washing. Coal, iron ore, barytes and kaolin have their impurities removed by these methods. Hand-picking is frequently resorted to for the purpose of removing rich lumps of mineral from gold, silver, copper, lead, zinc, or other ores.

Next in complexity is wet concentration. In its crudest form it is used for the treatment of alluvial ores of gold, tin, platinum, and alluvial material containing monazite, rare earths and diamonds. The mechanical treatment of gold, silver, lead, zinc and copper ores involves more elaborate machinery and a much more complicated cycle of steps. Where wet concentration methods, which depend primarily upon differences in specific gravities of the constituent minerals of the ore, do not give satisfactory results, flotation, magnetic and electrostatic separation, which depend upon physical properties other than specific gravity, can be considered and their suitability determined.

Of the solution methods the cyanide process is easily of the first importance. It is used for the treatment of gold, silver and gold, and silver ores. Not infrequently wet concentration is used in conjunction with it. Next in importance is the leaching of oxidized copper ores by the use of solutions of sulphuric acid. While many solution methods have been proposed for the treatment of ores other than gold and silver, it is worthy of note that no one of them has passed beyond the experimental stage with the exception of the acid-leaching of copper ores. The field is, in spite of this fact, a promising one.

Smelting methods are applied to iron, copper, gold, silver, lead and zinc ores. Where ores are "high grade" they frequently are sold to smelters without preliminary treatment. In the case of "low-grade" ores some mechanical method as indicated before is necessary in order to prepare a rich product which is sent to the smelter for treatment.

The Examination of Ores

The examination of ores for the purpose of determining methods of treatment is in itself a common enough procedure and involves methods which are well known and in most cases easily applied. The elaboration of a systematic method of examination has the advantage of bringing to a student the possibilities of the problem and compensating for his lack of practical experience. There have been relatively few attempts to do this, and it is my purpose to present such a system and discuss its limitations.

Taking the Samples

Few ore deposits are uniform, and the samples which are to form the basis of our examination must be taken with the view of representing, as accurately as samples can represent, the extremes of variation and the averages of the ores which have been exposed in the mine workings. The deposits may present three distinct divisions, the upper or oxidized portion, the intermediate or enriched portion, and the lower or primary portion. In some cases the ore problem may concern all three zones, while in others the oxidized portion may be relatively insignificant and the enriched portion important, or both the oxidized and enriched portions important and the primary zone unimportant. In other cases the primary zone may be of greatest importance. The relative importance can be determined by the relative quantities of ore and gross values represented by the three divisions. Whether one, two or three divisions are considered the procedure is essentially the same for each. An average sample is taken from each zone. This is done by making a number of sample cuts and combining the material from all. The possibility of dividing the ore into "first-class" or shipping ore and second-class or "mill ore" should be considered also. Here the metallurgist has to consider the mining problem. If it is possible to separately mine the two classes or readily separate them after breaking, then samples are taken of each class. This feature may apply to all three zones. The result of the sampling will be to give in the most general case from three to nine separate samples.

Oxidized	First Class	Second Class	Unseparated
Intermediate	....	....	....
Primary	....	....	....

No hard and fast rule can be laid down for the size of the samples. It is well to provide ample material and, if it is suspected that many tests will have to be carried out, from 500 to 1000 lb. of each sample may be advisable. For the small-scale tests the gross samples can be quartered to 100 lb. The taking of the samples is best done under the supervision of the metallurgist, and while they are being taken he should examine the general features of the ore in place. The physical nature of the ore, the manner in which it breaks and the nature of the mineralization are important points. A series of specimens of minerals typical of the ore and lumps of the ore itself should be gathered for future study. If it is obvious that stopes will be carried partly in the wall-rock, specimens and samples of the walls should be taken.

Samples and specimens for examination should be carefully marked and protected from any possible contamination.

Assays and Analysis

Each sample is reduced and a sample for assay and analysis taken. An assay for gold and silver and an analysis for the more important metals are made. While in many cases a complete analysis is unnecessary, I am very much in favor of making it. It will at least serve to check the possibility of the presence of unusual or unsuspected constituents.

Mineral Determinations

The lump-ore specimens are next examined and the minerals determined. Each mineral is separated and tested. Distinction is, of course, made between valuable and gangue minerals. The unusual minerals present are determined from the collection made at the time of sampling. Where it is possible to separate clean mineral fragments the specific gravity of the constituent minerals is determined. The percentage mineralogical composition is then figured.

Physical Examination

The specific gravity of the ore in the different samples is determined. This is not as easy as it appears. If the ore is compact, determinations upon lumps are sufficiently accurate. Several pieces should be tested and the average specific gravity calculated. If the ore is porous probably the best method is to determine the

approximate specific gravity by taking large pieces and determining their volume by sand displacement. The specific gravity is also calculated from the percentage mineralogical composition. The pore space of a given ore can be determined from the calculated and determined specific gravities. The hardness of the individual minerals and the approximate hardness of the ore should be tested and determined. Any definite structure such as banding, brecciation and planes of weakness should be noted. Plasticity or toughness or other pronounced physical characteristic should also be noted. For the physical examination the lump specimens are preferable to the test samples.

Mineral Association

The general nature of the mineralization of the ore will have been determined from studies made in the mine. The detailed study is made upon the type specimens previously collected. Ores from the standpoint of mineralization may be divided into massive, banded, laminated, disseminated, fracture-plane, and irregular. The terms are in common use and no definitions are necessary. Where only one mineral is associated with the gangue the size of the individual grains and aggregations of grains and crystals should be determined. In most ores the valuable mineral aggregates vary greatly in size, and it may be very difficult to determine the average size. In this case the extremes and the relative importance of each should be determined. For example, the aggregates may be for the most part of large size, say walnut size, or they may all be small, say of the size of wheat grains. Where relative terms are used for the description of sizes they should be defined within certain limits.

Aggregates may consist of two or more crystals. Note the number of crystals, the tenacity with which they adhere to one another in the individual aggregates, the shape of the aggregate, whether it be irregular, cubical, lenticular, sheet-like or tabular and the prevalency of the form habit. In addition, where two or more heavy minerals are associated, either as individual crystals or aggregates of crystals, note the nature of the association, the relative size and shape of the individual grains, and whether one mineral is included within the crystals of the other or they come together like the parts of a mosaic.

Where minerals are coarsely crystalized and the color and luster of the individual minerals sufficiently marked to admit of ready recognition, the examination of the lump ore or the broken pieces of the sample can be effected by use of a hand magnifying glass or by simple inspection. In the case of most copper, lead, zinc and some silver ores, the simple methods mentioned suffice. When the minerals are finely crystallized, intimately associated or differentiated with difficulty, then the method of examining a polished surface of the ore with the metallographic microscope is in order. A number of type pieces are selected and significant faces smoothed and polished. Individual mineral aggregates may be selected and prepared in the same way. Where differentiation is not pronounced reagents can be used to bring out differences in texture and color by etching. Thin sections of the ore are also prepared and examined with the petrographic microscope. In the case of a very complex ore the three methods enumerated above may be necessary, but it is surprising how much can be accomplished by the simple method of examining a number of broken fragments by the first method.

Crushing and Panning

Certain ores do not give satisfactory results by the above methods. Gold ores and many silver ores fall into this division. The relatively small quantity of the gold and the smallness of the individual particles usually prevent its recognition. Where several sulphide minerals are present the ore may be coarsely crushed and separated by a needle into its constituent minerals. By weighing and assaying each portion the presence and proportion of gold in each can be determined. In the case of fracture-plane mineralization the mineral on the fracture planes can be scraped off and assayed and the association of gold with it determined. The heavy sulphide minerals in a gold ore are usually in a finely divided condition and it is not feasible to separate by picking. The simplest method is to crush a given portion through a 20, 30 or 40-mesh screen and then concentrate it in water by means of a pan or batea.

The products obtained are concentrate, sand and slime. The concentrate should be examined for the presence of "free gold." With a microscope the size, shape and nature of the gold particles can be observed. In some cases the gold particles can be seen projecting out of particles of sulphides or attached to pieces of gangue. By weighing the products and assaying, the proportion of gold in each can be determined. By amalgamating the gold in the concentrates the proportion of free or liberated gold can be determined. By comparing the results obtained from similar tests on more finely crushed portions it is possible to determine the proportion of gold which is free, the proportion which is intimately associated with the sulphides, the proportion which is intimately associated with the gangue particles and the proportion which is in an extremely finely divided condition and associated with the slime.

With silver ores a similar series of tests can be made and the distribution of silver minerals determined. In the case of sulphide silver ores amalgamation is not satisfactory. With oxidized silver ores the concentration test is apt to be unsatisfactory. With cinnabar ores and ores where the valuable mineral is in very small bulk and finely divided the concentration test can be applied if the difference between the specific gravities of the gangue and valuable mineral is marked. The test has the somewhat objectionable feature that different results are obtained with the same material where it has been crushed to different sizes. This is due to the fact that the valuable mineral is liberated to a different degree with each crushing. The proportion of valuable mineral slimed is increased also with increased fineness of crushing. By running parallel tests on three portions, each crushed to a different degree of fineness, results of sufficient value can be determined.

The products of each test should be examined with the microscope. The concentrate will show whether the silver or other valuable mineral has been separated in part from the other heavy mineral or not. The sand portions will show whether mineral is conspicuously locked up in the gangue grains. The microscopic examination of the slime portion usually is not satisfactory on account of the difficulty of differentiation. The microscopic examination is qualitative only; the assay of the portions gives the quantitative results. Mineral associations are determined directly from the microscopic examination, and indirectly from the comparison of parallel tests on different portions, in each of which the degree of liberation of the mineral particles is different.

Use of Solvents

Solvents can in some instances be applied advantageously to the examination of gold and silver ores. The solvents are solutions of potassium cyanide, nitric acid, nitrohydrochloric acid and hyposulphite of soda. The results which can be obtained by their use will be better understood by considering examples. Crush a

portion of the sample to a 40-mesh screen size. Thoroughly agitate it for from twelve to twenty-four hours with a strong cyanide solution, say, 2 per cent. Then throw the mixture on a filter and wash the residues thoroughly. Dry and assay the residue. The difference in assay values will represent the amount of soluble gold which has been liberated in crushing. Gold tellurides are not soluble in cyanide solutions, and if these be present a different procedure is advisable. The residue obtained after the use of the cyanide solution is transferred to a roasting dish and cautiously roasted in the muffle. It is then treated a second time with a cyanide solution and after washing is assayed. By determining the gold in the cyanide solutions the result of the test is: Weight of gold in final residue or unliberated gold; weight of gold liberated by roasting; weight of gold soluble in cyanide solution and liberated by crushing. By repeating the test on portions crushed to different sizes the relation between the degree of crushing and the degree of liberation of the gold can be determined.

If a silver ore is to be tested, in which the silver minerals present are cerargyrite and argentite the procedure is as follows: Agitate a known weight of the ore which has been crushed to a 40-mesh size with a 1 to 4 solution of sodium hyposulphite for twenty-four hours. Throw on a filter and thoroughly wash. Digest the residue with nitric acid, using the concentrated acid and boiling for at least an hour. Dilute, filter and wash and assay the residue for silver. The silver in the nitric acid solution can be precipitated by sodium chloride, filtered out and determined by fire assay or wet methods. The results obtained are: Weight and proportion of silver present as silver chloride; weight and proportion of silver present as silver sulphide; weight and proportion of silver not liberated.

Solubility tests are of value in indirectly determining the nature of the valuable compounds present where they cannot readily be identified by direct methods. Obviously they are more or less limited in their application and obviously the results are sometimes open to question.

Use of Heavy Solutions

This method of separating associated minerals is unfortunately of very limited application for ore examination. Most ore minerals have a high specific gravity, and while it is possible to separate the greater number of gangue minerals from the ore minerals, the separation of one ore mineral from another is the principal difficulty. The solutions which can be used are: Solution of potassium and mercuric iodides which gives a maximum specific gravity of 3.19. A solution of thallium mercuro-nitrate which gives a maximum specific gravity of 5.3 at 76 deg. C. A solution of zinc chloride which gives a maximum specific gravity of about 2.

The first solution could be used to separate heavy from light minerals or a light from a heavy gangue mineral. The second solution would apply to a large number of miscellaneous minerals, but the heavy minerals of gold, silver and copper, zinc and lead would not admit of separation. The third solution is used for separating dirt, pyrite, rock, etc., from coal. The use of heavy solutions is a last resort. If the direct methods of observation and chemical analysis and the indirect methods of determining solubilities fail to give satisfactory results, then try the heavy solution.

Conclusion

If the physical and chemical nature of an ore is understood, and if the nature and association of the minerals constituting the ore are known, then the method or methods of treatment can be decided upon. The limitations of ore-dressing, solution and smelting methods from the economic, mechanical, physical and chemical standpoints are fairly well established. The mechanical appliances for drying, crushing, sizing, classification, concentration, sorting, washing, dewatering, filtration, magnetic separation, etc., have reached a high state of development. Mechanical appliances for conveying, elevating and excavating are available. Many examples of the arrangements of mills and reduction plants are to be found in technical publications. The metallurgist thus marshals three lines of thought, the ore, the fundamental steps in the treatment, and the mechanical appliances necessary to carry these out.

While a detailed study of the ore is essential it is not necessary in every case to carry out the general method described. The experienced metallurgist will know where the line can be drawn and can save himself unnecessary work. In addition certain tests are applied without, or with very limited, preliminary ore studies, and if favorable results are obtained the information may be sufficient to decide upon a method of treatment. Confirmatory tests are also carried out. These are first performed upon a small scale, and then the most successful repeated upon as large a scale as the available apparatus permits. Mill runs are often used for the determination of the details necessary for the design of the ore-treatment plant. They serve the additional purpose of confirming the studies and deductions of the metallurgist.

Golden, Colo.

The Ostwald Process of Oxidizing Ammonia to Nitric Acid

BY FRED C. ZEISBERG

Within the past year a great deal of interest has been shown in the "nitrogen problem" and considerable agitation has been rife with respect to making the United States independent of foreign supplies of nitrates in the event of war. One phase of this nitrogen problem is the catalytic oxidation of ammonia. The following article collects practically everything which has appeared in the literature concerning this process. It does not claim to present anything new, but simply aims to bring into a condensed and rational form the various references which have appeared from time to time.

The process of oxidizing ammonia to nitric acid is commonly known as the Ostwald process, not because this process was invented by Wilhelm Ostwald, but because the problem of the catalytic oxidation of ammonia was first attacked by him in a scientific manner and solved so successfully that this reaction could be used on the commercial scale. In the following pages all processes of oxidizing ammonia catalytically, and there are several of them, will be treated under the general head of the "Ostwald Process."

As early as 1839 Kuhlman[1] found that ammonia could be oxidized to nitric acid in the presence of catalytic agents. He mentions Cu, Fe, Ni, Pt and even $Cu(OH)_2$. Motay[2] mentions the use of lead manganate and permanganate, sodium manganate and lead chromate. In 1891 Warren obtained ammonium nitrite when ammonia and oxygen were passed over platinized asbestos at a dull red heat. Marston, in 1900, secured nitric compounds by passing the gaseous mixture over hot copper and other similar contact bodies.

That ammonia could be oxidized with ease was then well understood when Ostwald took up the study of the reaction in 1900. He discovered the conditions under which the reaction proceeded, and on the laboratory scale could easily obtain a yield, as HNO_3 on the NH_3

[1]Annalen der Chemie, 1839, 29, 281.
[2]Berichte der Deutschen Chemischen Gesellschaft, 1871, 4, 891.

taken, of over 85 per cent. Platinized platinum, *i.e.*, smooth platinum roughened by depositing upon it a thin layer of platinum sponge, was found the best catalyser, platinum black or sponge alone proving far too active. It was also found that only a thin layer of the catalyst worked best and that the gas mixture must be passed over the catalyst at a high velocity. A thick layer of catalyser or a low gas velocity caused the HNO_3 already formed to break down further into elementary nitrogen and water.

Having perfected the mechanical details of his process, Professor Ostwald, in 1902, applied for patents in the principal countries of Europe and in the United States. Because of prior publication of the essential features as scientific facts no patent was allowed in Germany. French Patent No. 317,544, English Patent No. 698 of 1902, Swiss Patent No. 25,881 and U. S. Patent No. 858,904, dated July 2, 1907, were allowed, however. The latter patent mentions the use, as catalysers, of palladium, iridium, rhodium, the oxides, especially the higher ones of manganese, lead, silver, copper, chromium, nickel, cobalt, vanadium and molybdenum; though platinum is best. The contact mass is heated to 300 deg. C., and the heat of the reaction then maintains it at the proper temperature. It is necessary to pass the gas at such a rate that a slight increase in rate would result in the appearance of unconverted ammonia in the exit gases, otherwise the yield will suffer. One of the claims also mentions a heat exchanger, whereby the heat of the exit gas is given up to the entering gases.

In 1909 a factory was built at Gerthe, near Bochum, Westphalia, with an annual production of 2400 tons of 53 per cent nitric acid. According to Norton[3] the operation of this factory has been very successful. A private communication states that from January, 1911 to August, 1912, this plant obtained an efficiency of 89.6 per cent on a monthly production of 130 tons of ammonium nitrate. The efficiency of conversion was 83 per cent and the efficiency of the absorption was 97 per cent. This plant operates on coal-tar ammonia, which is interesting in view of statements recently made in the literature that nothing but ammonia made from cyanamid was suitable in an oxidation process. Commercially, this factory is understood to have been a success.

According to another article[4] the above factory makes 2000 tons of ammonium nitrate per annum. This product has never appeared on the market, so it is presumably taken by the German government. In 1912 and in 1913 this company paid 8 per cent dividends to its stockholders.[5]

In 1910 the process was purchased by the Nitrates Products Co., Ltd., London, who took over the Gerthe plant. This company was promoted[6] by Mr. A. S. Barton and reorganized under the name of the Nitrogen Products & Carbide Co. and is capitalized[7] at £2,000,000. A new plant was erected at Vilvorde, Belgium, which produced 40 to 50 per cent nitric acid, higher strengths being produced by concentrating with sulphuric acid. Nitrates, Ltd., built cyanamid works at Alby, Sweden, and Notodden, Norway. In addition it expects to develop 400,000 horsepower in Iceland at the Ditterfoss, and three additional water power sites in Norway to produce a total of 600,000 horsepower. Recent articles[8] indicate that the present name of this company is the Nitrogen Products & Carbide Company, and that their finances have been considerably mismanaged, so that it has been necessary to assess the stockholders. No nitric acid is being made by them at the present time, their only factory, at Vilvorde, Belgium, being in the hands of the Germans.

A more recent article[9] states that the experience of countries other than Germany and Belgium has been very unfavorable as regards the Ostwald process, and that it is doubtful whether a single Ostwald plant is now in use outside of Germany.

The fact that no patent protection exists in Germany results in the greatest secrecy being observed in connection with the details of the process, and it is practically impossible to find statements of much value in the literature. This is especially true since the outbreak of the European war, no articles of any authoritative nature having been published recently.

The original converters were so constructed that an exchange of heat occurred between the incoming gas and the outgoing gas. This served not only to keep the catalyser at the proper temperature of 300 deg. C., because of the strongly exothermic character of the reaction $NH_3 + 2O_2 = HNO_3 + H_2O$, in which ninety-seven calories are evolved[10], but also served to regulate this temperature, even with considerable variations in the rate of gas flow. The thickness of the catalyzer layer and the gas velocity are so chosen that the time of contact between the two does not exceed one one-hundredth of a second.[11]

The proportions between the NH_3 and the air can be varied considerably. If an excess of NH_3 is used ammonium nitrate is the end product. If the NH_3 and air are so proportioned that the relation is that shown in the equation $NH_3 + 2O_2 = HNO_3 + H_2O$, and no water is dripped on the absorption towers, the maximum strength of nitric acid theoretically obtainable is 77.8 per cent. Ostwald himself[12] states that no less air should be used than represented by the equation $2\,NH_3 + 7\,O = 2\,NO_2 + 3\,H_2O$. In this case passing the gases very rapidly would result in obtaining a mixture of ammonium nitrate and ammonium nitrite in the exit gases.

According to Camille Matignon[13] the above equations do not represent the reaction correctly, as at the temperature of the reaction neither NO_2 nor HNO_3 can exist. The equation should hence be written $2\,NH_3 + 5\,O = 2\,NO + 3\,H_2O$. Of course, if an excess of air is used the NO would readily be oxidized to NO_2 as soon as the temperature is sufficiently reduced. This process of oxidation begins as soon as the temperature drops below 600 deg. C., but cannot become complete until the temperature drops to 140 deg. C.[14] At this lower temperature, moreover, the reaction velocity is very low, so that an appreciable time must elapse until the reaction becomes complete.

Apparently the only diagram of a converter ever published is one recently appearing[15] in an abstract of an article by G. Schüphaus in *Metall und Erz*, 1916, Vol. XIII, 21. In this converter the catalyzer is a platinum gauze, electrically heated to 700 deg. C. The gases enter below and pass upward through the gauze, no heat exchange being effected. At this temperature the conversion is almost quantitative, steam and nitric oxid (NO) being the end products, which would indicate that the reaction equation is $4\,NH_3 + 5\,O_2 = 4\,NO + 6H_2O$.

To keep the gauze heated, electricity is supplied at 25 volts and 135 amp., viz., 3.375 kw. No definite state-

[3]Special Agents Series No. 52, U. S. Dept. of Commerce and Labor.
[4]Electrical Review (London). 1911, 69, 531.
[5]Chemical Trade Journal & Chemical Engineer, 1915, LVI, 553.
[6]Journal of the Society of Chemical Industry, 1915, XXXIV, 125.
[7]Zeitschrift fur Angewandte Chemie, I, 1914, 48.
[8]Chemical Trade Journal & Chemical Engineer, 1915, LVI, 45 and 553; 1915, LVII, 26.
[9]Scientific American Supplement, Sept. 25, 1915.
[10]Electrochemical and Metallurgical Industry, 1906, IV, 137.
[11]U. K. Patent No. 8300 of 1902.
[12]U. S. Patent No. 858904.
[13]Chemical Trade Journal & Chemical Engineer, 1914, LIV, 179.
[14]Transactions American Electrochemical Society, 1909, Oct. 28, 29, 30.
[15]Metallurgical & Chemical Engineering, 1916, XIV, 425.

ment is made as to the capacity of a converter, but judging from a description, included in the article, of an ammonia gas purifying apparatus connected with the factory, three converters handle from 125 to 1250 kg. of NH_3 per day. Hence one converter can probably handle about 240 kg. per day or 10 kg. per hour. Since at 85 per cent conversion, 10 kg. of NH_3 will make 31.5 kg. of HNO_3, 100 kg. of HNO_3 will require about 10.75 kw.-hr. to keep the catalyzer hot.

The amount of platinum necessary to effect the conversion is about 47 grams per 100 kg. of HNO_3 per twenty-four hours.[16] The platinum loss due to wear and tear is about 3 per cent per month, and the elements have to be completely renewed once a month. Since fairly high prices can be obtained for platinum scrap the cost of renewal is the cost of supplying the platinum due to loss and the cost of exchanging the scrap platinum for new platinum.

It has not been found possible to ascertain the dimensions of a converter, but what information is available would point to the use of only small converting units, containing perhaps not more than 50 grams platinum per unit. The converters are built of iron up to the contact element, and beyond this of iron lined with aluminium. According to a patent[17] to Ostwald (German No. 207,154) nickel steel is not attacked by hot, nitrous gases and it can hence be used in place of aluminium-lined iron. At a point far enough away from the converter for condensation to occur, the gas lines must be made of an acid-resisting material, such as chemical-ware.

Since this process is a catalytic one, it suffers from the disadvantages of all catalytic processes, namely, the contact substance is "poisoned" by certain substances, which must be very carefully removed from the entrance gas by a suitable purification treatment. It is presumably for this reason that statements have appeared to the effect that only ammonia from cyanamid is suitable for this process, and that ammonia from coal tar, even when carefully purified, is likely to cause trouble by poisoning. An interesting bit of information from the other side is that the Oesterreichische Verein für Chemische und Metallurgische Production[18] has patented (German Patent 276,720), a process of purifying ammonia from cyanamid with caustic alkali and earth alkali solutions. When this was not done it was found that despite a careful filtration of the gas, to remove dust, the platinum contact elements became brittle and covered with a coating of silicic acid, after being in use only a short time. This was due to the presence in the gas of silicon, phosphine and acetylene.

To show that considerable work has been done on the oxidation of ammonia by investigators other than Ostwald, there are shown below several patents. Thus Frank and Caro (German Patent No. 224,329), propose the use of thorium oxid, or thorium oxid in combination with the oxids of other rare metals.

Fr. Baeyer & Co. of Elberfeld (German Patent No. 168,272), use cupric oxid, ferric oxid, etc. A current of air containing 4 to 5 per cent NH_3 is passed over the catalyzer heated to 600-750 deg. C. Above 650 deg. the NH_3 is converted into N_2O_3 exclusively.

Jones, Morton & Terziev (U. S. Patent No. 1,037,261) use the plumbates of magnesium, zinc, aluminium or cadmium, heated to 700-750 deg. C. The conversion to N_2O_3 is practically complete and the heat of reaction is sufficient to maintain the catalyzer temperature with but little pre-heating of the gases.

Rohmer (U. S. Patent No. 1,096,392, assigned to Farbewerke vormals Meister, Lucius und Brüning), patents the addition of only sufficient air to NH_3 so that the hydrogen of the ammonia removes all the oxygen of the air. The exit gases contain then only nitrogen, steam and oxids of nitrogen. By removing the two latter by condensation, pure nitrogen, available for the manufacture of ammonia by synthesis, is left. This corresponds to French Patent No. 453,845.

Schick (U. S. Patent No. 971,149, assigned to Chemische Fabrik Griesheim Elektron) patents the manufacture of a catalyzer suitable for causing the oxidation of ammonia. Tile is dipped in a platinum chlorid solution, dried and heated, causing the deposition of platinum black. The tile is then baked, causing the platinum to collect in minute globules. This catalyzer is claimed to retain its efficacy much longer than the platinized platinum recommended by Ostwald.

The above list does not claim to be complete. It is inserted simply to show that there are many investigators working on this particular problem. It is probable that of the processes mentioned above, the one of Frank and Caro has been developed to the greatest extent. Thus, Frank S. Washburn[19], president of the American Cyanamid Company, states that there has recently been developed a new process for the oxidation of ammonia, which does away with the limitations of the Ostwald process. The units can be made large or small and their cost is rather low.[20]

It is reported[21] that the Frank and Caro process of oxidizing ammonia has been developed in Germany to the extent of producing nitric acid at the rate of 120,000 tons per annum. The guaranteed efficiencies of two of the processes are from 90-95 per cent. An English company (Nitrates, Ltd.), is establishing cyanamid nitric acid factories throughout the allied countries of Europe and guaranteeing an efficiency of 90 per cent. It thus appears that commercially the oxidation of ammonia has proved successful and that it may be considered to be a well-established industry.

Regarding the cost of the process, only one detailed estimate of cost has been encountered in the literature. This is an abstract[22] from the Iron and Coal Trades Review (London) of May 23, 1913, containing a complete estimate of the cost of a small English factory for making nitric acid out of ammonia liquor.

Below is given a revision of this estimate based on American conditions, and considered only from the standpoint of conversion cost, *i.e.*, it is assumed that a supply of pure ammonia gas is already available.

In this estimate it is assumed that there are thirty converters in one building and that in a separate building is the absorption and condensing apparatus, consisting of five absorption towers 60 ft. high. Three coolers and one storage tank are used in supplying acid to each tower. The necessary pans, montejus, compressors, etc., are all included. It is further assumed that each converter unit produces 200 kg. of 36 deg. (53 per cent) nitric acid per day and that the total output per month is 148.4 tons of 53 per cent nitric acid = 78.7 tons HNO_3 = 173,500 lb. HNO_3.

Plant for conversion (converters)	$5,000
Condensing and absorption plant	17,500
Foundations for towers and iron work	5,000
Acid storage tanks	750
Air compressor and motor	3,000
Platinum,[23] 1500 g. at $1.67	2,500
Buildings and foundations	10,000
Unforeseen outlays	3,750
Total	$47,500

The running expenses are:

Power.—For lifting the liquid in the absorber house

[16]Scientific American Supplement, Sept. 13, 1913, 162.
[17]Journal of the Society of Chemical Industry, 1909, XXVIII, 365.
[18]Die Chemiker Zeitung, 1915, 848.
[19]Metallurgical and Chemical Engineering, 1915, XIII, 218.
[20]Transaction of the American Electrochemical Society, 1915, XXVII, 385.
[21]Metallurgical and Chemical Engineering, 1916, XIV, 418.
[22]Scientific American Supplement, Sept. 13, 1913, 162.
[23]This is equivalent to $51.80 per troy ounce.

and for direct air pressure, 12 to 15 horsepower, and for running a fan 5 additional horsepower, say 20 horsepower altogether. This means 14,400 horsepower hours per month (30 days) and at 2.5c. per horsepower-hour, the power would cost $360.

Platinum.—For the whole plant thirty contact elements, weighing 50 grams each are required. The total wear and tear may be estimated at 1.5 grams per day or 45 grams per month. The contact elements can be used a month or six weeks, after which they must be scrapped as old metal and replaced with new. This exchange can be made for about 6 cents per gram. Assuming an exchange once per month, the cost of exchanging the 1455 grams would be $87.30, and the cost of replacing the 45 grams lost would be $75.00, a total monthly expenditure for platinum of $162.30.

Wages.—For superintending and operating valves two men are sufficient per shift; for cleaning, a third man is required (original article). In larger installations it is assumed that these three men could care for twice as much apparatus. Assuming the foreman would get 45 cents, his helper 35 cents, and the cleaner 30 cents per hour, the labor cost would be $396.00 per month on the three-shift basis. A superintendent at $150 per month could easily look after a plant four times the size.

The monthly expenditures would then be:

Power	$360.00
Platinum	162.30
Wages	396.00
Repairs	125.00
Superintendence	37.50
Interest and depreciation at 15 per cent per annum	594.50
	$1,675.30

This makes the cost of conversion 0.965 cent per pound HNO_3.

The original investment cost per metric ton of HNO_3 per year is hence $50.30 for the converting and absorption apparatus and the conversion cost, including interest and depreciation as shown above, is $21.30 per metric ton. In applying the above figure the cost of the ammonia necessary to make a ton of HNO_3 would have to be added to the conversion cost. Thus, with ammonia at 7.5 cents per pound the cost of HNO_3 per metric ton would be, on the basis of an 85 per cent conversion, $52.50 for NH_3 + $21.30 for conversion or a total of $73.80 per metric ton of HNO_3. It should be remembered that this is for HNO_3 in the form of 36 deg. Baume or 53 per cent nitric acid.

To see how the above costs compare with the costs obtained by other estimators or with other processes, it might be mentioned that an original investment cost of $50.20 and a conversion cost of $23.50 per metric ton of nitric acid per annum were assumed by O. Dieffenbach.[24] In his estimate he assumed 10 per cent interest on the capital investment. This same calculation gives the cost of concentrating HNO_3 from 53 per cent to 93 per cent as $12.43 per metric ton of HNO_3 or 0.563 cent per pound HNO_3.

From another source[25] the original investment cost is $51.90 and the conversion cost is $28.10 per short ton, which is equivalent to $57.20 for the original investment and $31.00 for the conversion cost per metric ton of HNO_3 as 53 per cent acid. The above estimate and the one in the preceding paragraph, as well as the detailed estimate on page 13, are for small plants. For large plants the article in the *Chemical Trade Journal* gives an original investment cost of $53.30 per short ton and a conversion cost of $35.65 per short ton, which is equivalent to $58.80 for the investment cost and $39.30 for the conversion cost per metric ton of HNO_3, as *concentrated acid.* Some additional figures given in this same article would indicate that the investment cost, when making 53 per cent HNO_3 in large plants, would be $37.40 and the conversion cost $21.20 per metric ton of HNO_3. This would give a concentrating cost of $14.45 per metric ton of HNO_3 or 0.656 cent per pound HNO_3.

Washburn states[26] that "roughly speaking and with power at $10.00 per horsepower year there is to the credit of ammonia from cyanamid about half the cost of weak nitric acid made by the arc process, available for oxidizing the ammonia to nitric acid. The indications are that the cost will not amount to more than half this difference." With power at $10.00 per horsepower year, a metric ton of HNO_3 made by the arc process and in the form of 53 per cent acid would cost about $50.00, which, according to the above statement, would make the conversion cost from $12.00 to $15.00 per metric ton of HNO_3. This estimate should be regarded conservatively, however, as it is based only on general statements.

Summarizing the above estimates, we obtain the following table in which the figures under (*a*) refer to small plants and those under (*b*) to large plants:

Per Metric Ton of 2205 Lbs. of 100 Per Cent HNO_3	Scientific Amer. Suppl.	Dieffenbach	Chem. Trade Journal	Washburn
Investment cost	$50.30	$50.20	(a) $57.20 (b) 37.40[27]	......
Conversion cost to 53 per cent acid	21.30	23.50	(a) 31.00 (b) 21.20	$12–$15
Concentrating cost	....	12.43	(b) 14.45	......
Conversion cost to 93 per cent acid	....	35.93	(b) 39.30	......
Conversion cost to 93 per cent acid per lb. 100 per cent HNO_3	....	1.632c.	(b) 1.783c.	......

There is a fair amount of agreement among the first three estimates, but the estimate of Washburn is so much lower that it should be regarded with reserve, especially when it is considered that it is only a general statement upon which the estimate is based. On the other hand, it must be remembered that this process has made immense advances in Germany very recently, and as Washburn's statement was made at least a year later than the appearance of the other estimates, it is quite likely that this process can be carried out more cheaply than the older estimates would indicate.

The true figure probably lies somewhere between the two, *i.e.*, the conversion cost is probably about $18 per metric ton of HNO_3 in the form of 53 per cent acid, or 0.816 cent per pound HNO_3. To this must be added the cost of the ammonia and the cost of concentrating the acid to 93 per cent. Even with ammonia at 5 cents per pound and a conversion of 85 per cent, the ammonia would cost 1.587 cent per pound HNO_3 and the concentrating cost would hardly be less than 0.375 cent; so that HNO_3 in the form of 93 per cent acid, could hardly cost less than 2.778 cents per pound by the Ostwald process.

The question of the profitableness of the Ostwald process, on the basis of the above figures, depends on several considerations. The price of ammonia is governed by the price of sodium nitrate, the prices of these two substances always being approximately equal when calculated to a basis of their nitrogen content. If it costs less to convert ammonia to nitric acid than it does to convert soda to nitric acid, it will naturally be more profitable to use the Ostwald process than the present process. In this conversion the cost of sulphuric acid must be included in the latter process. But, consideration must also be given the fact that the yields with the two processes are different, that with the Ost-

[24] Die Chemische Industrie, 1914, 265.
[25] Chemical Trade Journal and Chemical Engineer, 1914, 283.
[26] Transactions American Electrochemical Society, 1915, XXVII, 385.
[27] This becomes $58.80 when the concentrating apparatus is included.

wald being usually taken as 85 per cent, that with the present process at 97 per cent. Therefore, in order to break even and with equal cost of nitrogen in the raw products, the Ostwald process must be capable of converting its raw product into nitric acid more cheaply than the present process in order to take care of the greater amount of nitrogen lost in the conversion, and the difference in conversion costs must hence be greater the higher the initial cost of the nitrogen.

The cost of conversion by the Ostwald process, 93 per cent nitric acid being the end product, we have seen could hardly be less than 1.191 cent per pound HNO_3. The cost of nitric acid made from nitrate of soda is probably at least 1.75 cents per pound for labor, repairs, etc., and sulphuric acid. The cost for nitrogen, with nitrate of soda at 2.64 cents per pound, would be 3.750 cents for the retort method and $97 \div 85$ of this or 4.280 cents for the Ostwald process per pound HNO_3. These figures are arrived at by assuming that 1.42 lb. of nitrate of soda are used per pound 100 per cent HNO_3, which is about the case with a yield of 97 per cent; $1.42 \times 2.64 = 3.75$ and $97 \div 85$ of $3.75 = 4.28$ cents. If nitrate of soda should fall to 1.5 cent per pound, below which it is hardly conceivable it could ever go, the nitrogen cost per pound HNO_3 would be $1.42 \times 1.5 = 2.13$ cents for the retort process and $97 \div 85 \times 2.13 = 2.43$ cents for the Ostwald process.

We would then have:

	Ostwald	Retort
Nitrate of soda at 2.64c., NH_3 at 13¼c.:		
Cost of conversion	1.191	1.750
Nitrogen cost	4.280	3.750
Total cost	5.471	5.500
Nitrate of soda at 1.5c., NH_3 at 7.5c.:		
Cost of conversion	1.191	1.750
Nitrogen cost	2.430	2.130
Total cost	3.621	3.880

From these figures it can be seen that with the present price of nitrate of soda the Ostwald process can make nitric acid for only a fraction of a per cent less than the retort process. If the price of nitrate of soda decreases, however, and with it the price of ammonia, the Ostwald process becomes increasingly more profitable. With nitrate of soda at 1.5 cent per pound the cost of the Ostwald process for making nitric acid would be 93 per cent of the cost of making it by the retort process.

It is a little difficult, at first, to see why the Ostwald process should not be profitable now, using by-product ammonia, which can certainly be produced for less than 13¼ cents, the ammonia price corresponding to a nitrate of soda price of 2.64 cents per pound. A little consideration will show, however, that it is much more to the producer's advantage to sell his by-product ammonia for 13¼ cents than to convert it into nitric acid to be sold at only a very slight advance over this price.

It is also a little difficult to see why the Ostwald process should be increasingly more profitable as the nitrate of soda price falls. The reason is that as the nitrate of soda price falls the ammonia price falls correspondingly. The conversion cost remains the same with both processes, however, being approximately a half cent per pound of HNO_3 higher with the retort process. At the present price of nitrate of soda this difference is neutralized by the larger amount of raw material needed by the Ostwald process on account of its lower conversion yield. As the cost of the raw material falls, however, the raw material makes up an increasingly smaller proportion of the total cost, so that the higher conversion cost of the retort process begins to influence more and more the total cost.

The figures obtained in the foregoing estimate do not agree very well with the statement of Washburn[20] that the cost of making nitric acid from ammonia in Europe at the present time is about 70 per cent of the cost of making it from soda, even though his statement is based on a 90 per cent conversion for the contact process. Of course, it is unknown whether the above statement refers to normal conditions in Europe, or the present abnormal ones.

Regarding the advantages and disadvantages of the Ostwald process, they seem to sum up as follows:

Advantages.—The process is continuous, which makes for a maximum return from the investment. It is capable of installation in small units, which makes for flexibility in operation. The exit gases from the converters are several times as concentrated as those from any arc furnace, which allows of enormously cutting down the size of the absorption apparatus. The raw product, ammonia, is easily obtainable in the United States, making us independent of foreign supplies in case of war. The power costs are very low, hence the plant could be located almost anywhere.

Disadvantages.—It is only a step and not a complete process, hence the plant would have to be located with respect to economy of freight on incoming supplies, either cyanamid or ammonia liquor. It is hardly profitable unless the cost of ammonia drops to a figure that is improbably low.

Conclusion.—So far as information is available it would hence appear that the Ostwald process, and this term is meant to include all processes of the catalytic oxidation of ammonia, is hardly in a position to compete with even the present process of manufacturing nitric acid from nitrate of soda. Even with a considerable reduction in the price of ammonia the possible profit is so small and the reliability of the figures on which the cost estimates are based is so problematical that it would seem a rather doubtful proposition to entertain.

It should be remembered that the foregoing reasoning is based on a yield of only 85 per cent for the Ostwald process. If it could be possible, for example, to raise the yield to 97 per cent, the yield usually obtained by the retort process, the Ostwald process could produce nitric acid for about a half cent per pound less than the retort process. There is no general information available at present, however, which would indicate that the conversion efficiency of the Ostwald process is much in excess of the 85 per cent used throughout this paper.

When it comes to comparing the cost of nitric acid made by the Ostwald process with the cost of nitric acid made by the arc process, relatively accurate figures for which are available in the literature, the cost by the Ostwald process is seen to be so high that there is little use giving it further consideration.

It should be emphasized again, however, that due to the secrecy observed in the country where the process was evolved, with respect to making public the details of the process, the information obtained from the literature cannot be credited to too great an extent. This information is the best we have at hand, however, at the present time. After the cessation of hostilities in Europe it may come to light that the Germans have perfected and cheapened this process to such an extent that it might prove worth considering, for installation in small units at isolated points. It seems very unlikely, however, that it can ever be cheapened to an extent where it can compete on the large scale with nitric acid by the arc process, unless a much better yield of ammonia can be obtained than seems to be the case at the present time. Ammonia will always be too valuable *per se*, to consider making cyanamid, how-

[20]Metallurgical & Chemical Engineering, 1916, XIV, 418.

ever cheaply, for the sole purpose of converting it to nitric acid.

There is appended a bibliography which collects the references given throughout the text, and in addition gives several other references which were not directly referred to. Some of these are only short notices, others long articles giving much detailed and general information, but all have a bearing on the process under consideration. This list is not by any means complete, but the compiler believes that no important reference in any of the more well-known journals has been overlooked.

Wilmington, Del.

Utilization of Atmospheric Nitrogen—Thomas H. Norton, Special Agents Series No. 52, Dept. of Commerce and Labor, 1912.
Salpeter und sein Ersatz—Konrad W. Jurisch. S. Hirzel, Leipzig, 1908.
Die Oxydation des Ammoniaks zu Salpetersäure und Salpetriger Säure—Ed. Donath and A. Indra. Ferdinand Enke, Stuttgart. 1913.
The Facts in the Nitrogen Case Now Before Congress—Frank S. Washburn, 1916. A pamphlet issued for private circulation.
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Smithsonian Institute Report, 1913, 359.
Zeitschrift für Angewandte Chemie, 1914, I, 48.
Metallurgical and Chemical Engineering, 1906, 137; 1913, 438, 476, 714; 1915, 213, 218, 241, 314, 325, 620; 1916, 418, 513. (Until the end of 1909 this journal was known as "Electrochemical and Metallurgical Industry.")

ADDENDUM

Since the above article was written two patents have appeared (U. S. 1,193,796 and 1,193,797) which might be construed to alter somewhat the reasoning expressed in the conclusions. These patents deal with the oxidation of ammonia and claim to obtain a 95 per cent conversion. Their novelty lies in the cooling of the ammonia-air mixture up until the very time it comes in contact with the hot catalyser, in distinction to the principle of heat exchange mentioned in Ostwald's original U. S. patent. Because no heat is carried to the catalyser by the gases it must be heated in some other manner, preferably electrically.

As the claim that a 95 per cent conversion can be obtained appears only in a patent specification and has not yet been substantiated, so far as any information available in the literature would indicate, it would seem as yet a little too early to assume that these patents have any serious bearing on this problem. Later developments may show them to be of great importance, but time will be required to prove this.

Western Metallurgical Field

Company Reports

Inspiration Copper Company's report for the year 1915 states that copper production began in June, 1915, the first unit of the new mill going into operation on June 29. During the last six months of the year copper production amounted to 20,445,670 lb., of which 20,067,310 lb. was recovered from 778,851 tons of ore concentrated and 378,360 lb. from oxide ore shipped to smelter. The ore averaged 1.7 per cent copper, of which 0.226 per cent was in oxidized form. Tailings assayed 0.373 per cent copper, of which 0.18 per cent was oxidized. Flotation concentrates averaged 37.63 per cent copper, and table concentrates 13.12 per cent. The average assay of all concentrates made was 32.67 per cent copper, and the percentage recovery of all copper was 79.95. Average percentage recovery of sulphide copper was 88.56. Ratio of concentration was 24.6:1. The following tabulation of costs is given for the treatment of 778,851 tons of ore, producing 20,067,310 lb. copper.

	Per Lb. Copper	Per Ton Ore
Mining	2.644c.	$0.68110
Coarse crushing	0.113	.02910
Ore hauling	0.079	.02025
Concentrating and royalty	1.889	.48675
Concentrate hauling	0.006	.00160
	4.731c.	$1.21880
Smelting, freight, refining, marketing, etc.	3.455	.76420
	8.136c.	$1.98300

The saving of sulphide mineral by flotation has improved since the mill first went into commission and has not only exceeded the expectations of a year ago, but is now better than the average for 1915. For the month of February, 1916, the saving of sulphide copper was 91.1 per cent. Coal tar continues to be used as the chief component of the flotation-oil mixture. An interesting item in connection with the test mill is that it treated 373,705 tons of ore and paid for its cost of construction, operating expense, the present average cost of mining on ore treated, and left something besides. The cost per ton of daily capacity for the equipment of the property to mine and mill 14,400 tons daily is given as $833, of which $625 was for equipment of mine and mill, water supply, power, mill site, tailing land, railroad, etc., and $208 for advanced mining expenditures to prepare for an output of 14,400 tons per day. Operating costs for mining and milling at Inspiration probably will range from $1 to $1.15 per ton of ore.

The annual report of the **Hollinger Gold Mines, Ltd.,** is acompanied by a report recommending consolidation of the Hollinger property with those of the Acme Gold Mines, Ltd., Millerton Gold Mines, Ltd., and Claim No. 13,147 of the Canadian Mining & Finance Co., Ltd. During 1915 Hollinger produced gold bullion of the value of $3,169,814, an increase of $480,459 over the previous year, in spite of the lower grade of ore treated, the comparative values per ton being $13.67 in 1914 and $10.11 in 1915. Net profits amounted to $1,916,467, from which dividends of 52 per cent were paid amounting to $1,560,000. The surplus now amounts to $1,478,210. The summary of ore reserves shows a gross value Dec. 31, 1915, amounting to $16,031,600, nearly three million dollars greater than a year previous. The milling record shows the treatment of 441,286 tons of ore, of which 334,705 tons came from the Hollinger and the balance from the Acme. Detailed information on the treatment of the Hollinger ore follows: Average value per ton $10.11; average daily tonnage, 917; stamp duty per 24 hr. running time, 14.72 tons; value per ton of tailings, 40 cents; cyanide consumption per ton of ore, 0.574 lb.; zinc consumption, 0.467; tons solution precipitated per ton ore, 1.909; zinc added per ton solution, 0.244 lb.; average value pregnant solution, $5.074. The cost of milling the Hollinger ore was $0.999 per ton. Concentrates have been stored for treatment, amounting to 9500 tons with a gross gold value of $81,763. This material will now be reclaimed as rapidly as possible. Costs for 1916 are expected to increase owing to the advance in cost of supplies, ranging from 10 per cent to 500 per cent.

Steady Demand for Ferromanganese.—There is a steady inquiry for prompt ferromanganese. Foreign material is quoted at $175 per ton at seaboard. Domosetic ferromanganese is quoted at $170, with some "electrolytic" offered at $165 per ton.

The Metal Tie-Up in Electrolytic Refining

BY LAWRENCE ADDICKS

Most electrolytic refining processes have to compete with fire processes which are as a rule less satisfactory technically, but which turn out the product in a very much shorter time. This slow turn-over imposes heavy interest charges on account of the large investment in plant which it implies and from the necessity of financing the metals in process. The plant investment and the amount of metals locked up are closely related to the current density employed, but as the power required increases nearly as the square of the current density, a point is soon reached where the cure is worse than the disease.

TABLE I

Metal	Normal Market Value Dollars per lb.	Electrochemical Equivalent Grams per Ampere-hour	Quotient X 104
Iron	0.01	1.04	1
Lead	0.04	3.86	1
Zinc	0.06	1.22	5
Copper	0.15	1.19	13
Nickel	0.30	1.09	29
Silver	9.00	4.03	232
Gold	300.00	2.45	12700

The case varies greatly with the metal under consideration, depending upon its electrochemical equivalent and market value. Some idea of this variation can be obtained from an inspection of Table I, which takes the ratio of these two factors as a measure of the relative costs. Although this table is inexact in that it ignores voltage and other minor factors it shows how in the case of lead a handicap has been removed enabling electrolysis to compete with the best of fire processes, while gold is electrolyzed in but few plants not under Government auspices, where locked values are not of any importance.

The question is somewhat complicated by the fact that the bullion being electrolyzed is generally a mixture of two or more metals, each of which is to be recovered. The refining of blister copper carrying silver and gold will serve as an example upon which to base further discussion of the problem.

Copper refining contracts specify certain permissible elapsed times for the return of or payment for the values in the bullion to be refined, varying from 45 to 75 days for the copper and from 60 to 90 days for the silver and gold. It is evident that the earlier the metals can be put on the market the sooner their cash value can be put to earning money elsewhere and, therefore, that each day that the process locks up the values has a definite cash value. This is not greater than 6 per cent, however, as the banks consider warehouse certificates based on metals in process satisfactory collateral for loans up to a high percentage of their market value in ordinary times. Taking copper at fifteen cents a pound, the interest value of a sixty-day refining allowance is three dollars a ton, and each ton-day costs five cents, with corresponding values for the silver and gold contents. The cost of refining is made up of operating expenses, metal losses and metal interest, and it is the purpose of this article to examine the last.

Metals are tied up in process for three quite different reasons which might be stated as commercial, technical, and balancing. Commercial policy makes it desirable to hold incoming bullion at times before putting it into process until certain conditions are fulfilled, such as agreement of assays, or such a state of weather as shall obviate the necessity of moisture allowance when weighing; or fluctuations in the metal market may make it advantageous to go to extra operating costs to cut down what normally would be considered proper stocks in process or delay the purchase of metals lost in process; finally it is good policy to endeavor to carry reasonable stocks of refined shapes on hand so as to be able to adjust shipments to unexpected changes in orders, steamer sailings and the like. It is quite reasonable to have 10 per cent of the total tie-up in copper due to such causes.

Then we have the values locked up for technical reasons which may be classified as metals truly in active process, metals circulating in slags, etc., metals permanently tied up in furnace bottoms, etc., and metals forever lost to be charged into operating costs as metal losses.

Finally there are the stocks of pig, anodes and cathodes which it is necessary to carry in order to insure smooth, continuous operation regardless of minor irregularities in arrival of pig or breakdowns in some parts of the process. To these the name of "balancing" metals has been given for want of a better term.

The total metals tied up are, of course, shown by the balances due customers on the metal books of the plant, but these figures give no data of value in the analysis or control of the values. It is also customary to take annual physical inventories of metals on hand in order to determine accurately the metal losses for the preceding year. This indicates the metal tied up in each part of the plant but unfortunately in order to take a proper inventory without shutting down the process it is necessary to introduce temporarily radical changes in operation which greatly increase the tie-up. It is, therefore, necessary to rely upon a thorough understanding of the sources of locked values and of their relative importance and a constant scrutiny of conditions in order to control this important factor in the total cost of operating a copper refinery.

CLASSIFICATION

Fig. 1 gives a systematic classification of the sources of locked values which we shall proceed to take up item by item. The items under the heading "Commercial" may be dismissed with the arbitrary assumption of five days delay of copper, four days of silver and three days gold.

METAL IN PROCESS

Turning next to the delays for technical reasons and taking first "metals in process," Fig. 2 gives the direct course of the metals through the process ignoring all diversions.

The weighing, sampling, and handling of pig to the anode furnace properly occupiès one day. The refining and casting into anodes is a twenty-four hour operation. In the tank house conditions vary greatly in different plants, but representative eastern practice may be taken as 14 days cathodes and 28 days anodes, making an average age of 21 days for the two sets of electrodes. The refining furnace is operated on the same basis as the anode furnace, calling for one day. Certain parts of the plant are shut down on Sundays, but this is assumed to have no effect upon the final date of delivery of refined copper.

In the silver refinery the length of time required to recover doré from the slimes will depend greatly upon the impurities present, but it is not likely to be less than three days for dissolving the copper in the slimes and six days for furnacing them.

In the parting plant, assuming electrolytic parting is used, the anodes will probably last three days and the cathode crystals be cleaned up every few hours, making an average of one and a half days. The washing and melting of the silver sponge takes but a few hours, say half a day. The gold mud would be cleaned every three days and the boiling and melting take two days.

We can now sum up the time required as shown in Table II.

TABLE II

	Copper	Silver	Gold
Weighing and sampling	1	·	1
Anode furnaces	1	1	1
Tank house	21	21	21
Refining furnaces	1	—	—
Boiling slimes	—	3	3
Furnacing slimes	—	6	6
Parting dore	—	1.5	3
Melting silver	—	0.5	—
Refining gold	—	—	1.5
Melting gold	—	—	0.5
Total days	24	34	37

These figures show first that but about half the time allowed for refining is required by a straight passage through the process, thereby giving the goal we should strive to approach, and second that as would be expected the slow item is the electrolysis. This time can be lessened by cutting down the age of the anodes or of the cathodes or of both. Too light an anode increases handling costs and the percentage of anode scrap made, while too light a cathode runs up disproportionate charges for making starting sheets and decreases the productive hours of the tanks, which have to be cut out while drawing copper. As before stated the power charges mount very rapidly with increasing current density.

METALS CIRCULATING

The sample diagram shown in Fig. 2 would become an almost undecipherable confusion of lines were it expanded to indicate every movement of circulating metals. As we proceed from pig to cathode a fraction is diverted at each stage of the process and sent back to an earlier one.

Each of the furnace processes may be illustrated by the first diagram in Fig. 3 and both the copper electrolysis and the doré parting by the second except that there are no starting sheets in electrolytic parting processes, the silver being deposited in non-adherent crystals upon a fixed carbon or silver cathode.

The return arrows indicate circulating metals and the straight ones metals locked up continuously. The two cases are alike in their effect upon the process except that the former varies directly with the output while the latter are more or less constant for a given plant regardless of output. (Metals actually lost are a third case, but the quantities involved are small and are generally adjusted by systematic purchases so as to have but a negligible effect upon the time required for refining and they will be ignored in this article). Liquors partake of both characteristics, as a certain stock is

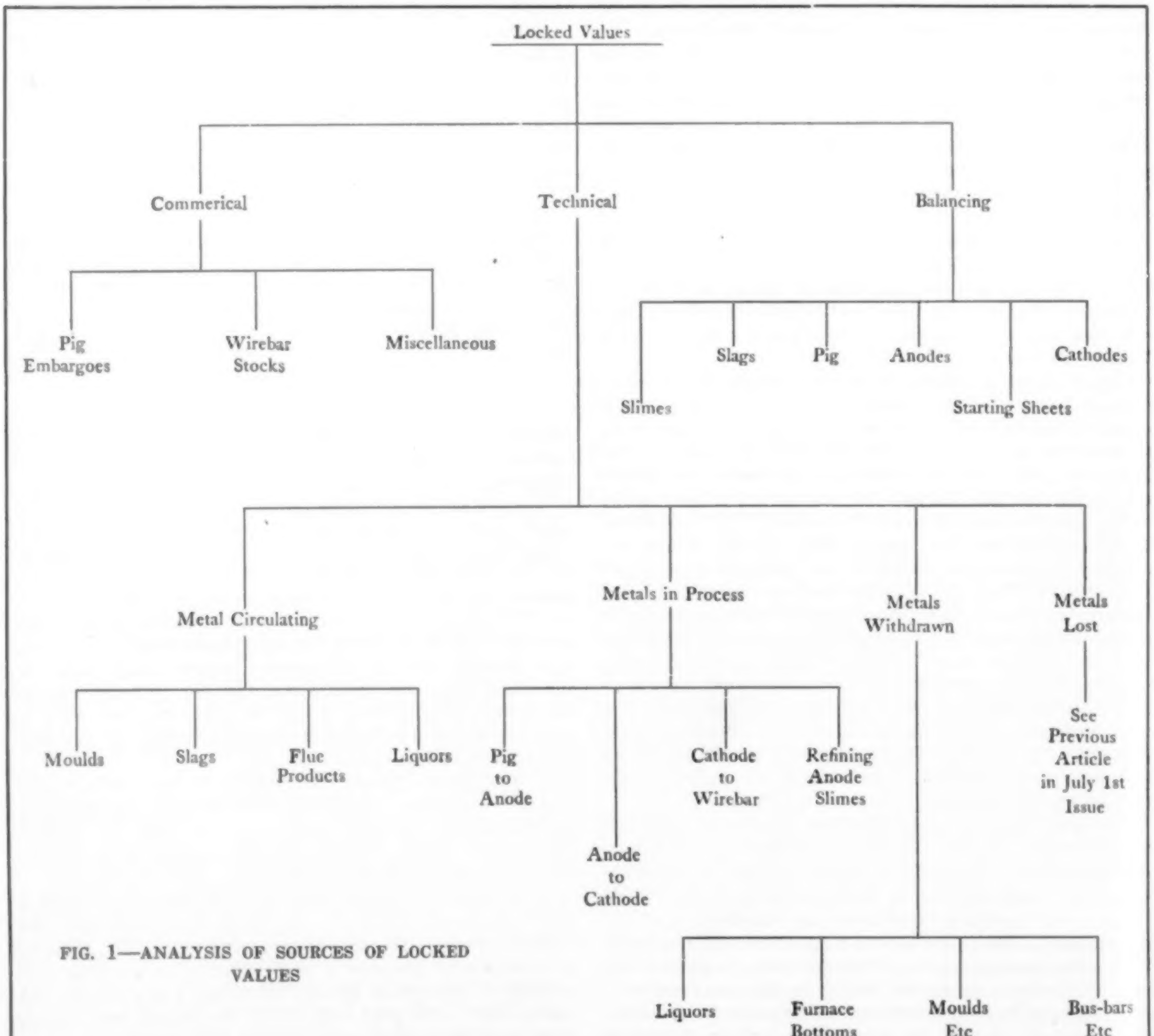


FIG. 1—ANALYSIS OF SOURCES OF LOCKED VALUES

required for starting up the plant while another quantity circulates through the purifying departments, etc.

Returning to the plan laid down in Fig. 1 we shall consider the metals circulating in slags, flue-products and liquors.

ANODE FURNACES

The first and simplest case is that presented by the anode furnaces; first because, if we ignore the small amount of values circulating in the drillings from sampling, the anode furnaces divert the first fraction from the entering pig, and simplest, because the slag and flue products have made return directly to the anode furnaces themselves after being reduced to pig in a cupola, giving a single fraction to consider.

The quantity of slag made by an anode furnace varies with the purity of the pig from less than 1 per cent of the charge to several per cent. The slag itself will run from 35 to 45 per cent copper and the silver and gold slagged will be proportionately less than the copper. We shall assume that we have made 1.5 per cent of the copper contents of charge in slag running 40 per cent copper and that the silver and gold slagging ratio is 0.85 and 0.45 respectively, with copper at 1.00. In flue dust we shall recover about 0.07 per cent of the copper and say 0.1 per cent of the silver and 0.05 per cent of the gold treated. Then we have other flue products such as the cobbing from repairs, and the quantity of this also varies greatly with the character of the bullion under treatment. We shall assume it to amount to 25 per cent of the metals in the slag. Then there is a negligible amount of bad production, scale, etc., charged back next day. We have therefore as a measure of the apparent shrinkage of the values in process, ignoring actual metal losses, the figures given in Table III.

TABLE III

Anode furnace diversions	Copper	Silver	Gold
Charged to furnace	1.0000	1.0000	1.0000
Slag contents	0.0060	0.0051	0.0027
Flue dust	0.0007	0.0010	0.0005
Cobbing, etc.	0.0015	0.0013	0.0007
Total diversions	0.0082	0.0074	0.0039
Net output	0.9918	0.9926	0.9961

The actual retreatment of these by-products does not take over a day, the process being simply reduction to big copper in a small cupola. In practice a great deal of time is lost in storage before retreatment, but this will be taken up later under "balancing" the process.

TANK HOUSE

The tank house has three circulating items; anode scrap, starting sheets, and liquors.

Anode scrap is the part of an anode remaining after it has been eaten away by the current until but a skeleton remains hanging from the supporting lugs. These lugs generally account for from 3 to 5 per cent of the total weight of the anode and this percentage represents the lowest possible anode scrap.

In practice the scrap made varies between 7 and 20

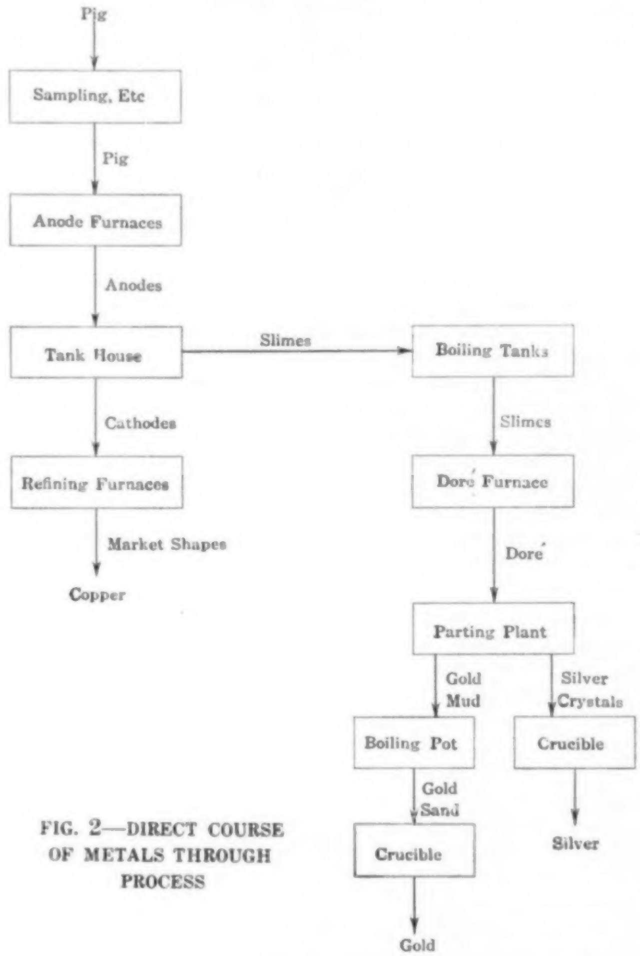


FIG. 2—DIRECT COURSE OF METALS THROUGH PROCESS

per cent. A poorly refined anode will dissolve unevenly and cause heavy scrap, while careful filling of the "holes" caused by drawing individual anodes which work out first will lessen the final scrap made. The best policy, however, is to refine the anodes thoroughly and take no chances on disturbed current distribution in the tanks due to "lace" anodes, so that a normal percentage of scrap will be about 14 per cent of the weight of the anodes charged. This scrap is subject to a charge

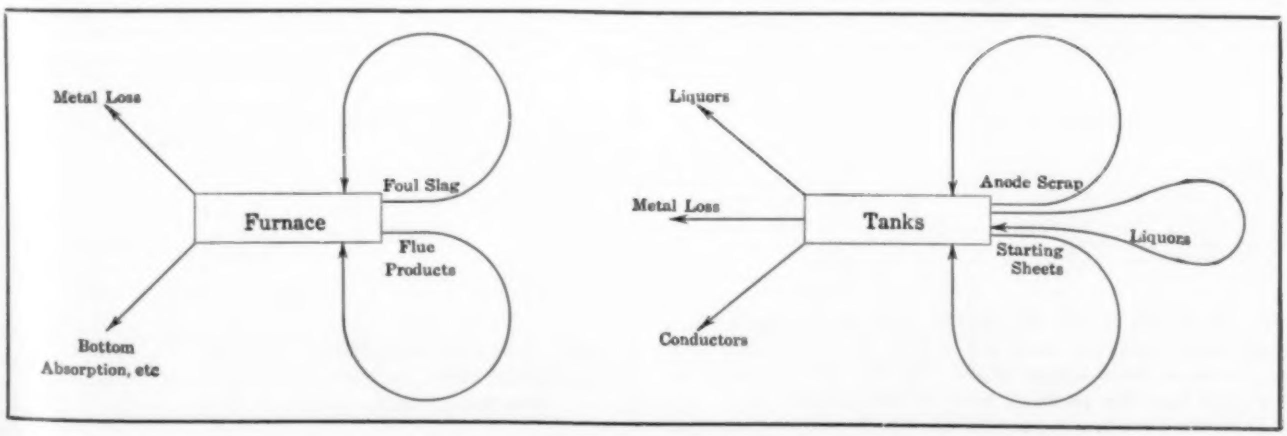


FIG. 3—TYPICAL METAL MOVEMENTS

of 28 days in the tank house plus the time required for the anode cycle.

The starting sheets are cathodes which are deposited upon greased copper plates and stripped as a thin sheet when they are about twenty-four hours old. They are used as mother sheets upon which they build up the cathodes proper. As the cathodes are drawn in fourteen days, one twenty-eighth of the number of tanks (each copper plate or "starting blank" yields two starting sheets) must be turned over to this service. Actually a little more than this is required for the manufacture of loops by which to hang the cathodes and to allow for bad sheets. The production of bad sheets will be considered negligible and one twenty-fifth, or 4 per cent, of the output will be considered to be in starting sheets which have been set back two days, one day depositing and one for attaching loops, etc., by this diversion.

The copper tied up in the electrolyte comes chiefly under the head of "metals withdrawn," but a certain amount circulates between the tank house and the silver building and the tank house and the purifying department. The first of these is a small item. The slimes are pumped over to the silver building as a soup carrying perhaps 5 per cent solids, but as the slimes amount to but about one and a quarter per cent of the anodes and as the electrolyte carries but 3 per cent copper, the total copper involved in the movement is but three quarters of a per cent of the anode weight. The slimes are settled out and the liquor returned in about twenty-four hours.

The proportion of liquor required for purifying depends, of course, upon the impurities present in the anode. In the first place there is a certain amount of copper dissolved chemically from the electrodes which would cause an accumulation of copper in the electrolyte were there no compensating factors. If the anodes are very free from impurities, insoluble anode tanks must be operated to recover about 2 per cent of the cathode output in order to strike a balance.

On the other hand if nickel is present in the anodes this dissolves electrochemically but is not deposited at the cathode, so that if much is met with a condition of actual insufficiency of copper in the electrolyte may obtain, calling for the use of shot towers.

Antimony may be precipitated chemically as oxychloride and arsenic electrolytically in the insoluble anode tanks. Iron should be adequately removed in the anode furnaces. Nickel, however, accumulates and must be removed by evaporating liquors.

It will thus be seen that quite different conditions may exist at different plants or at the same plant at different times. For our case we may assume that the equivalent of 1 per cent of the copper in the anode has to be regularly removed. Practically all of the copper contents of this solution will be eliminated in the three successive sets of insoluble anode tanks

TABLE IV

Diversions from Tank House

	Copper	Route
Entering	1.0000	
Anode scrap	0.1400	Anode furnaces
Starting sheets	0.0400	Tank house
Copper in slimes	0.0017	Tank house
Electrolyte to silver building	0.0075	Tank house
Electrolyte to purifiers	0.0100	Cupola
Total diversions	0.1992	
Net output	0.8008	

through which it will be passed as a first stage in the purification and we need not follow this further. We may assume that these tanks will be cleaned once in ten days and the product sent to the cupola.

Then we have the copper in the anode slimes returned from the silver building. This amounts to about 0.20 per cent of the copper in process, or say 0.17 per cent of the anode weight. It is returned to the tank house as copper sulphate and has about a ten-day cycle.

Summarizing, we have for a unit of anode copper entering the tank house the diversions given in Table IV.

REFINING FURNACES

The refining furnaces are similar to the anode furnaces as regards circulating metals except in that the quantity of by-products made is smaller owing to the practical absence of impurities and that a handicap exists owing to the necessity of sending these back through the cupola to the very beginning of the process. The values assumed for the anode furnace may be scaled down as given in Table V.

The bad production consists of defective castings which are charged back into the furnace next day. The

TABLE V

Diversions from Refining Furnace	Copper	Route
Charged to furnace	1.0000	
Slag	0.0030	Cupola
Flue dust	0.0001	Cupola
Cobbing	0.0010	Cupola
Bad production	0.0100	Refining furnace
Moulds	0.0200	Refining furnace
Total diversions	0.0341	
Net production	0.9659	

molds may be considered also as returned next day, the balance of the period by their use being considered under "metals withdrawn." We are assuming that the anode furnaces use cast iron and not refined copper molds. The small amounts of silver in gold in the refining furnace by-products are ignored.

SILVER REFINERY

We come next to the silver refinery. The anode slimes carry all the silver and gold, neglecting losses, and about 0.2 per cent of the copper, as already stated. For

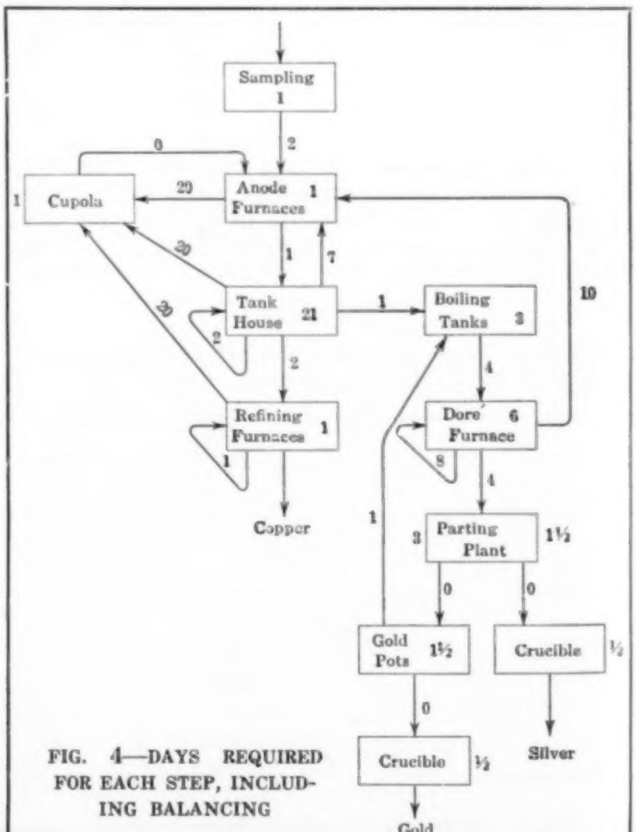


FIG. 4—DAYS REQUIRED FOR EACH STEP, INCLUDING BALANCING

our purposes the small amount of copper entering the doré furnaces may be neglected.

The next step in the treatment of the slimes is a reverberatory smelting. The slimes are melted and tend to form three distinct layers, bullion, matte, and slag. The slag is skimmed off and the matte, if small in quantity, as it should be if the copper has been properly removed in the slimes boiling tanks, broken up by blowing. The foul bullion is then refined to high-grade doré by cupeling without the addition of lead. The final by-products are two slags, flue dust and cobbing, all of which, after sorting out metallics, are sent to the anode furnace. We shall assume the data stated in Table VI.

TABLE VI

Doré Furnace By-Products

		Assay—Ozs. per ton	
	Weight	Silver	Gold
Slimes	2000	12,000	100
Poor slag	300	800	1
Rich slag	500	1,200	6
Flue dust	200	1,200	1
Cobbing	40	1,200	6

We can now build up a schedule for the reverberatory doré furnace. This is given in Table VII.

TABLE VII

Doré Furnace Diversions

	Silver	Gold	Route
Charged to furnace	1.0000	1.0000	
Rich slag	0.0250	0.0150	Doré furnace
Poor slag	0.0100	0.0015	Anode furnace
Flue dust	0.0100	0.0010	Doré furnace
Cobbing	0.0020	0.0012	Anode furnace
Total diversions	0.0470	0.0187	
Net output	0.9530	0.9813	

The doré is sent to the electrolytic parting plant, but as there is neither anode scrap, nor starting sheets, assuming the Thum-Balbach system with horizontal electrodes is employed, the only circulating values are in the wash waters from the crystal silver and these are so small that they may be neglected here. The same is true of the slags from the crucible melting of the gold and silver.

There is, however, some circulating silver from the refining of the gold anode mud. This mud may be considered half gold and half silver, so a quantity of silver just equal to the gold output is dissolved in the boiling kettles and sent back to the slimes boiling tanks. As we have assumed slimes with 12,000 oz. per ton of silver and 100 oz. per ton of gold this represents a diversion of 0.0083 or a net output of 0.9917.

SUMMARY OF CIRCULATING METALS

We are now in a position to revise Table II by the application of the diversion factors for circulating metals in order to show what proportion of the metals entering the process emerge directly in the period given

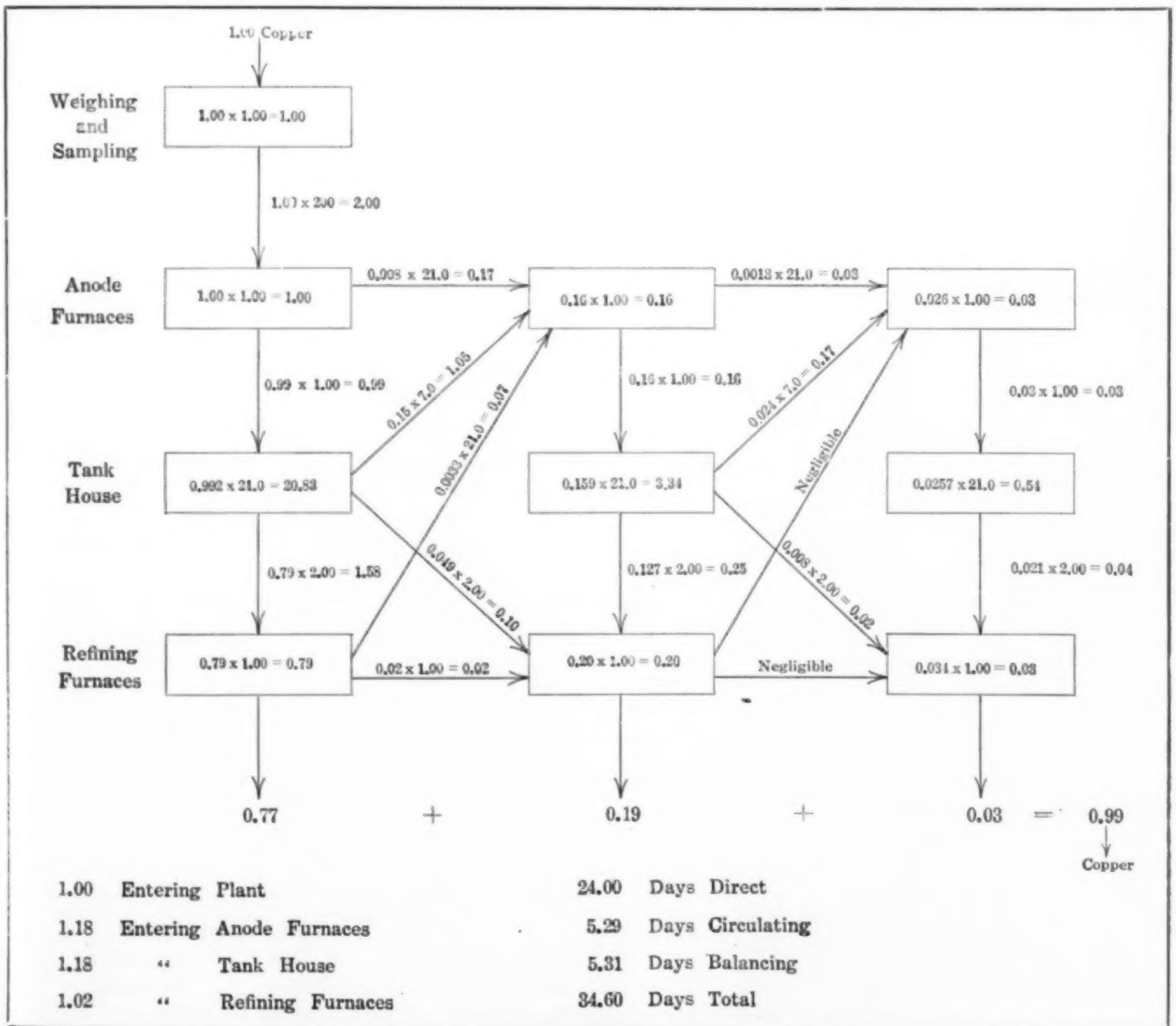


FIG. 5—COPPER

in that table. This summary of diversions is given in Table VIII.

TABLE VIII

Summary of Diversions

	Copper		Silver		Gold	
	Factor	Cumulative	Factor	Cumulative	Factor	Cumulative
Weighing and sampling.	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Anode furnaces........	0.9918	0.9918	0.9926	0.9926	0.9961	0.9961
Tank house	0.8008	0.7942	0.8600	0.8556	0.8600	0.8566
Refining furnaces	0.9659	0.7671	......	......	......	......
Furnacing slimes......	......	......	0.9530	0.8154	0.9813	0.8406
Parting Doré..........	......	......	1.0000	0.8154	1.0000	0.8406
Melting silver.........	......	......	1.0000	0.8154	1.0000	0.8406
Refining gold..........	......	......	0.9917	0.8086	1.0000	0.8406
Melting gold..........	......	......	1.0000	0.8086	1.0000	0.8406
Net product.........	......	0.7671	......	0.8086	......	0.8406

The figures of Table 8 show that but 77 per cent of the copper, 81 per cent of the silver, and 84 per cent of the gold entering the plant go directly through the process in the 24, 34, and 37 days shown by Table 2, the balance being diverted into by-products which require retreatment. The result of this is that the actual metals in process of treatment at various stages is greater than the pig receipts or cathode output by the amount of these circulating metals. It is also obvious that as these retreated metals start through the process a second time a portion is again diverted. There are several ways of evaluating this, the simplest of which is probably to work out several terms of a continued fraction, thereby ascertaining the total metals passing through each step of the process.

BALANCING METALS

In order to get the time element we must consider the "balancing metals," or stocks held at various points in the process in order to insure continuity of operation

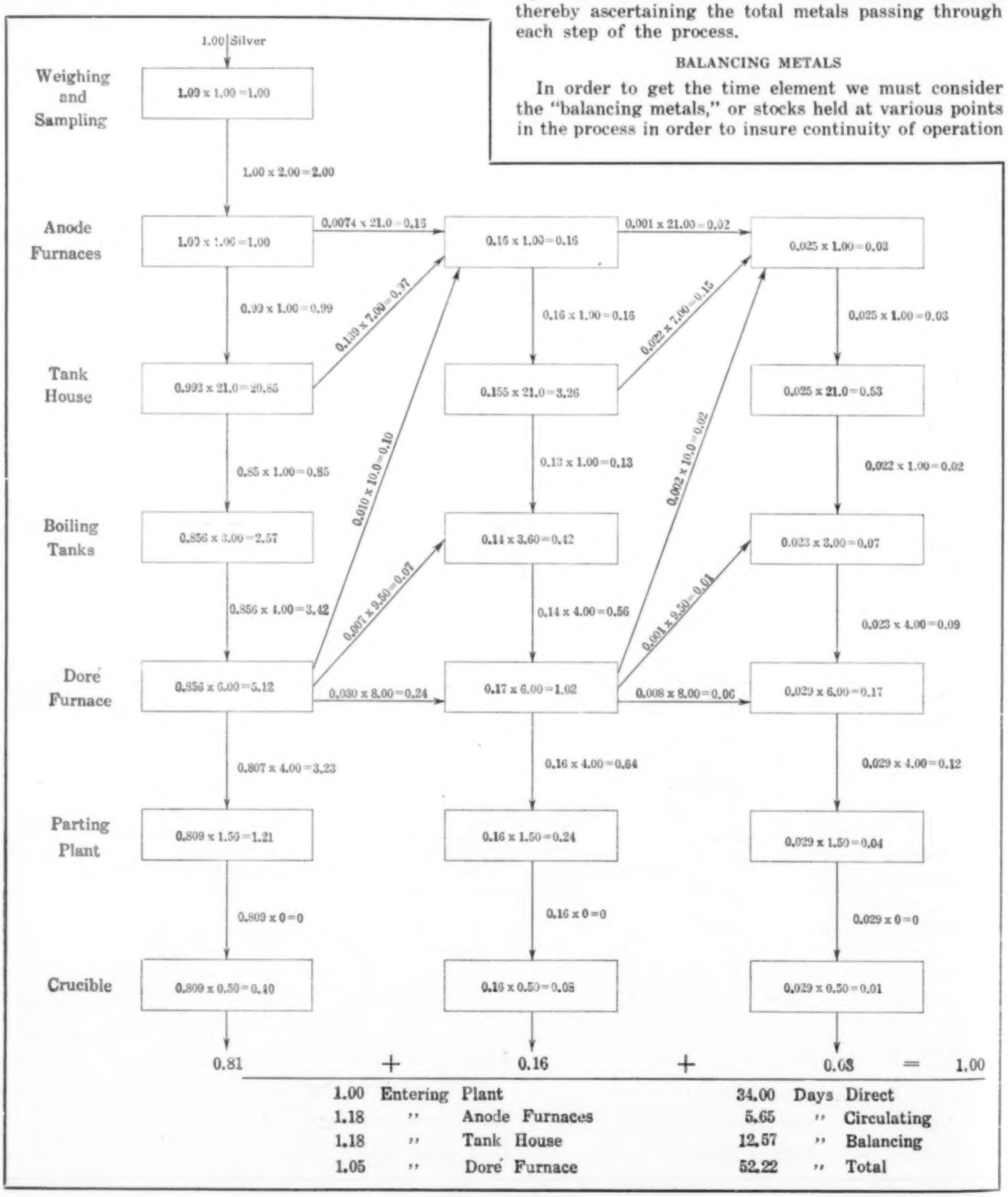


FIG. 6—SILVER

without disproportionate cost. This is done graphically in Fig. 4, where the numbers represent days. Where they occur between the rectangles representing steps in the process they stand for the average number of days output at that point held in stock; where they occur inside or alongside the rectangles they represent the days in process shown by Table 2.

We can now proceed to construct the diagrams showing the unit-days lost at each step and this has been done separately for the copper, silver and gold in Figs. 5, 6, and 7. Each vertical row in these figures represents one term of the continued fraction. Three terms are sufficient to approximate the total. In order to simplify the diagram the cupola has been omitted, although allowed for in the days given, and some items

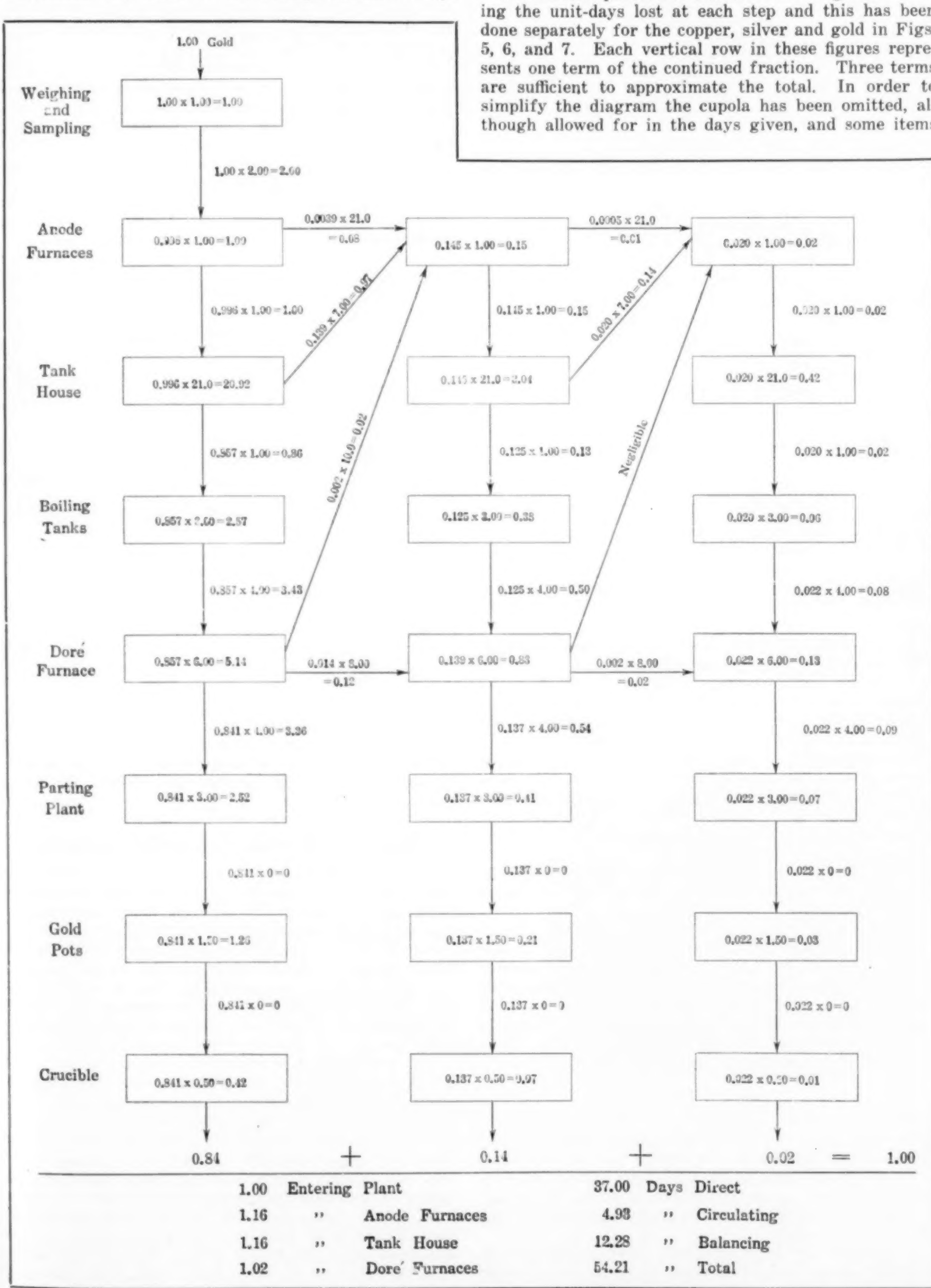


FIG. 7—GOLD

have been averaged in groups. The figures are units of weight times days equals unit-days, and as one unit of weight is shown entering the process the sum of the unit-days is the actual total days that unit is in process.

METAL WITHDRAWN

We have finally to consider the "metals withdrawn" by liquors, furnace bottoms, conductors, and molds. These are easily translated into unit-days by considering how long the plant would have to run in order to fill these storage vaults.

LIQUORS

We have two main bodies of liquor to consider, the copper sulphate electrolyte in the tank house and the silver nitrate electrolyte in the parting plant, the latter carrying negligible amounts of copper, however.

In the tank house in addition to the liquor actually in the tanks there is a large additional quantity in the piping system and sumps. In general in a large plant there is required about 20 lb. of liquor per pound per day of copper treated. As the electrolyte runs about 3 per cent in copper this is equivalent to saying that 0.6 days output of the plant will be required to stock up the electrolyte.

In the parting plant this factor is a little less, say 0.4 day, as there is not the circulating system to allow for.

FURNACE BOTTOMS

There are four main furnace bottom absorptions, anode, refining, cupola, and doré. The anode and refining furnaces are alike except that 18 per cent more capacity is required in the anode department as shown in Fig. 5, and that the refining furnace ties up no silver and gold. An anode furnace will absorb from 100 to 400 lb. of copper per square foot of hearth area, depending upon the age, thickness and composition of the bottom.

It is customary to start the soaking of a new bottom with material lean in silver and gold and in general the relative absorption of silver is lower than the amount to be expected from the grade of bullion treated; this ratio changes with age, however, and gold in particular seems to concentrate in the bottom.

For our purpose we may assume 0.40 days copper for the complete absorption of the furnace and flues of a refining unit. This will become 0.47 days for an anode furnace. The silver will be say 0.25 and gold 0.40. These figures must be increased about 30 per cent, however, for reserve capacity.

The cupola bottom absorption is relatively negligible. This is due to the fact that it is occupied on but a day's treatment of only a circulating by-product.

On the other hand, the doré-furnace bottom constitutes a very large item, due to the facts that it is a small furnace which means disproportionate brickwork, and that it treats something more than the entire silver and gold output in six day charges. The net result is that this accounts for about 12 days silver and 10 days gold.

The small absorption in the crucibles is neglected.

CONDUCTORS

We next have the copper tied up in conductors, etc., in the tank house and the silver in contact pieces leading the current in and out of the cells in the parting plant.

These copper parts in the tank house consist of busbars, cross rods (upon which the cathodes are hung) and starting blanks (the plates upon which the starting sheets are deposited).

It is customary to buy the main bus-bars outright as a charge against capital expense, so these do not enter into this discussion.

The other small parts are borrowed from the copper passing through the plant as they are made of refined copper and can be melted up at any time at a day's notice, were some extraordinary market condition to call for a final accounting in refined copper. Of course this loan has to be paid for in "metal interest" as it correspondingly lengthens the time required for refining. This method is really no different from that pursued in casting lugs upon the anodes in order to conveniently suspend them in the tanks.

The items in question amount to about 1.5 days production of copper.

The silver contact pieces in the parting plant are a small item, tying up about 0.1 of a day's production.

Finally we have the copper molds used for casting the wire bars, ingots, etc., and these tie up about 2.5 days production.

The total days lost from "metal withdrawn" is shown in Table IX.

TABLE IX

Metals Withdrawn

	Copper	Silver	Gold
Tank house electrolyte	0.60	....	....
Parting plant electrolyte	....	0.40	....
Anode furnace bottom	0.61	0.33	0.52
Refining furnace bottoms	0.52	....	....
Doré furnace bottoms	....	12.00	10.00
Conductors, etc	1.50	0.10	....
Moulds	2.50	....	....
Total days	5.73	12.83	10.52

We can now summarize the results of this review and Table X shows a total time required of 44 days for the copper, 69 days for the silver and 68 days for the gold.

TABLE X

Summary of Metals Tied Up

	Copper	Silver	Gold
Commercial	5.00	4.00	3.00
Technical—Direct process	24.00	34.00	37.00
Circulating	4.29	5.65	4.93
Withdrawn	5.73	12.83	10.52
Lost	....	....	....
Balancing	5.31	12.57	12.28
Total days	44.33	69.05	67.73

To these figures must be added any delays due to fires, strikes and other "unforeseen" causes, and it must further be remembered that running a plant at part capacity runs up the "metals withdrawn" and some other items.

Board of British Scientific Societies

On the initiative of the Royal Society (London) a Board of Scientific Societies has now been established for promoting the co-operation of those interested in pure or applied science, according to the *Iron and Coal Trades Review*. This supplies a means by which the scientific opinion of Great Britain may, on matters relating to science, industry and education, find effective expression; taking such action as may be necessary to promote the application of science to industries and to the service of the nation; and discussing scientific questions in which international co-operation seems advisable. The Board at present consists of representatives of twenty-seven scientific, including technical societies. The regulations give power to add to this number and to appoint as members of sub-committees individuals who are not necessarily connected with any of the constituent societies. An executive committee has been appointed consisting of the following members: Sir Joseph Thomson, O.M., P.R.S. (chairman), Dr. Dugald Clerk, Sir Robert Hadfield, Mr. A. D. Hall, Prof. Herbert Jackson (honorable secretary), Sir Alfred Keogh, Sir Ray Lankester, Prof. A. Schuster, Sir John Snell, Prof. E. H. Starling, Lord Sydenham, Mr. R. Threlfall.

New Sulphuric Acid Plant

The Construction of the Sulphuric Acid Plant and the Commercial Process of Manufacture of the Acid as Used by the United States Steel Corporation at Donora, Pa.

BY T. N. HARRIS

Sacrificing everything for time, work was begun on this plant in June of 1915, and the first acid ran over the towers during the night of Dec. 22, 1915. This record-breaking time for construction operations should go down in engineering history as a marked example of results obtained from co-operation and organization among engineers and superintendents in charge of construction work.

In the following paragraphs the writer will endeavor

TOWER BUILDING AND ROASTING FURNACE

to describe briefly the construction of the equipment used for the manufacture of sulphuric acid (H_2SO_4), at the same time tracing the ore from the time it is unloaded at the ore bins until it is placed in the roasting furnaces where the sulphur is liberated and combined with oxygen from the air. Attention then will be given to the sulphur dioxid (SO_2) gas, thus formed as it passes over the nitre furnace, thence through the towers and chambers until it is concentrated to 60 deg. Baumé and then pumped into the storage tanks ready for drawing off into tank cars to be shipped.

ORE-HANDLING PLANT

This plant consists of the ore bins, sampling and crusher buildings. Australian ore is used chiefly in this process owing to the fact that the percentages of zinc and sulphur run much higher than in our own native ores. Zinc runs about 50 per cent, sulphur 25 to 30 per cent, about 6 ounces of silver, small quantities of lead and iron and a slight trace of gold.

This ore is jet black, weighs 150 lb. to the cubic foot, and some of it is as fine as flour. Approximately one ton of acid is made from the sulphur gases driven off from one ton of ore.

SAMPLING

Before the ore is placed in the bins, or while it is being unloaded, a representative sample is taken for assaying purposes. This process is carried on in the sampling building, directly adjacent to the ore bins and which forms a part of the ore-handling plant.

This ore is received at the plant in box cars; thus it is unloaded by the shovel and wheelbarrow method. As the unloading takes place a certain quantity is set aside, the quantity being arrived at by the simple expedient of setting aside every tenth shovel or every tenth wheelbarrow.

This sample is then thoroughly mixed; about 5 lb. of it is placed in dryers to drive off the moisture. After a sufficient time has elapsed this moisture sample is weighed to obtain the percentage of moisture.

The remaining portion of the original sample is placed in a large dryer to drive off the moisture content, and is then run through a crusher which breaks up the lumps sufficiently to allow the ore to be more finely divided by a machine known as the rolls. The name of this machine tells the story of its duty. It consists essentially of two rolls or cylinders placed with their axes horizontal and their surfaces directly adjacent. The rolls revolve in opposite directions, and the ore on passing through is ground finer.

From the rolls the ore goes to the dividers, an arrangement for obtaining a mathematical division of the ore. This machine is a simple hopper arrangement with a slotted bottom, the alternate slots diverting the ore into two separate pans. The process may be repeated any number of times and thus as small a sample as wished may be obtained.

For assaying purposes the entire sample must pass through a hundred-mesh screen. In order that this condition may be fulfilled, the ore taken from the dividers is run through a pulverizer, which consists of two disks revolving in opposite directions and with arrangements for adjusting their proximity, thus assuring the passage of the final sample through a hundred-mesh screen.

ORE BINS

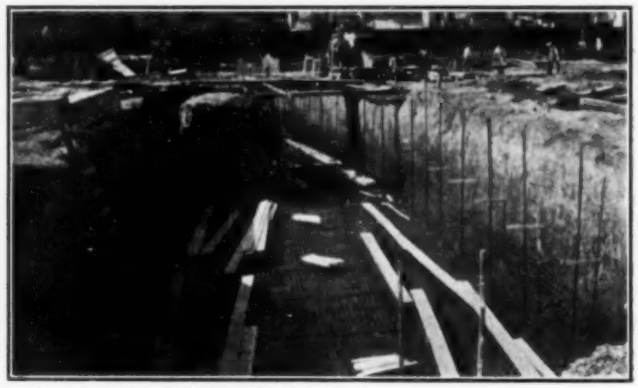
The bins are interesting from an engineering point of view, as they are wholly constructed of heavily reinforced concrete. They are ten in number, each bin being 70 ft. long, 20 ft. wide and averaging 18 ft. high, being 20 ft. high at one end and 16 ft. at the other. These are inside dimensions, so the total capacity of

90-FT. CONCRETE TOWER AT THE ORE BINS

the ten bins is 224,000 cu. ft., or approximately 15,000 tons of ore.

The walls separating the bins are 18 in. on top and average 32 in. at the bottom, being 3 ft. at the high end and 28 in. at the low end. They are reinforced longitudinally and vertically; longitudinally by ¾ in. square plain bars spaced 30 in. on centers, and vertically by 1 in. square plain bars placed 2 in. from each face spaced 6 in. on centers. Every third bar extends to within

DUST COLLECTOR FOUNDATIONS



ROASTING FURNACE TUNNEL

2 in. of the top of the wall while the two intervening bars extend only to the top of the middle third section of the wall. The end and side walls have the same reinforcement as the intermediate walls.

The bottom of the bins is a 2-ft. slab, reinforced longitudinally and transversely by ¾-in. square bars 12 in. on centers, excepting under the walls, where the reinforcement is 1 in. square bars running longitudinally and transversely along the top and bottom of the slab on 18-in. centers.

There was 3500 cu. yd. of concrete and 185 tons of reinforcing steel required for this work. The concrete in the bottom slab was a 1-2½-5 mix, while the walls were a 1-2-4 mix. Universal Portland cement was used exclusively in all the foundation work. The concrete for the ore bins was poured from two 90-ft. distributing towers rigged with a system of line gate chutes and completed in less than thirty days.

CRUSHER BUILDING

This building is enclosed by the same roof as the ore bins, the total length of the structure being 340 ft. and the width 75 ft. The equipment installed includes hoppers, screens, crushers, driers, dust collectors, skip hoists, storage bins, ore chutes, trestle for ore car and numerous electric motors.

The ore is taken from the bins by a 15-ton overhead electric traveling crane with a grab bucket and deposited in a large conical-shaped hopper, about 20 ft. in diameter. From the hopper it enters a revolving screen (42 in. diameter, 12 ft. long, ¾ in. perforations, 18 r.p.m) where the fines are separated and passed on into the revolving driers (Ruggles Coles Class A-14, 60 ft. long, 7 ft diameter, weight 42 tons) and the coarse shunted off into a No. 6 Kenedy gyratory crusher.

Upon leaving the driers the ore is caught in a bucket which is elevated by a skip hoist and deposited in the storage bins from whence it is taken by the ore car to the roasting furnaces.

The storage bins are accommodated on the 75-ft. level of the 130-ft. tower, which occupies the southern extremity of the building. This tower is 30 ft. wide and extends 75 ft. across from one side wall to the other. Besides the storage bins this tower accommodates a Newage separator (style No. 3) trestle for the ore car and six carbonate crushes of the roller type.

This plant is made up of two units whose operation calls for the use of twelve Westinghouse motors. Two 200-hp. motors drive the carbonate crushers, two 25-hp. motors operate the skips, two 65-hp. motors the driers, two 10-hp. for the screens, two 40-hp. the gyratory crushers and two 7½-hp. motors operate the fans to the dust collectors.

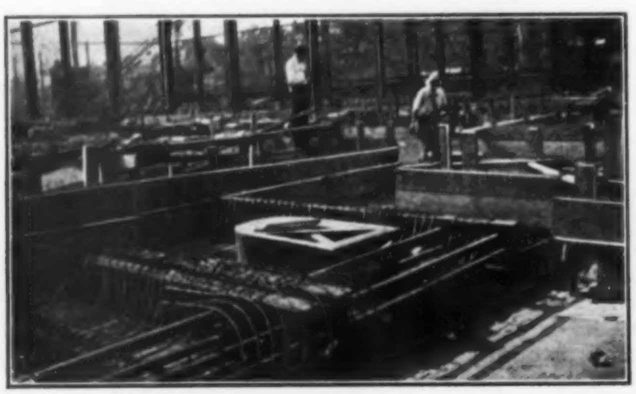
A 75-ft. reinforced concrete stack is used in connection with the driers. The structural steel used in the framing for the tower of this building is the heaviest type used on the entire work.

ROASTING FURNACES

The equipment necessary for roasting the ore and conveying the sulphurous gases to the nitre furnace includes the following: a large roast kiln, gas producer with large steel circular flues leading to the combustion chamber of the kiln, an air heater, rod alley, dust collector and kite-shaped flues leading from the roast kiln to the dust collector, thence to the nitre furnace.

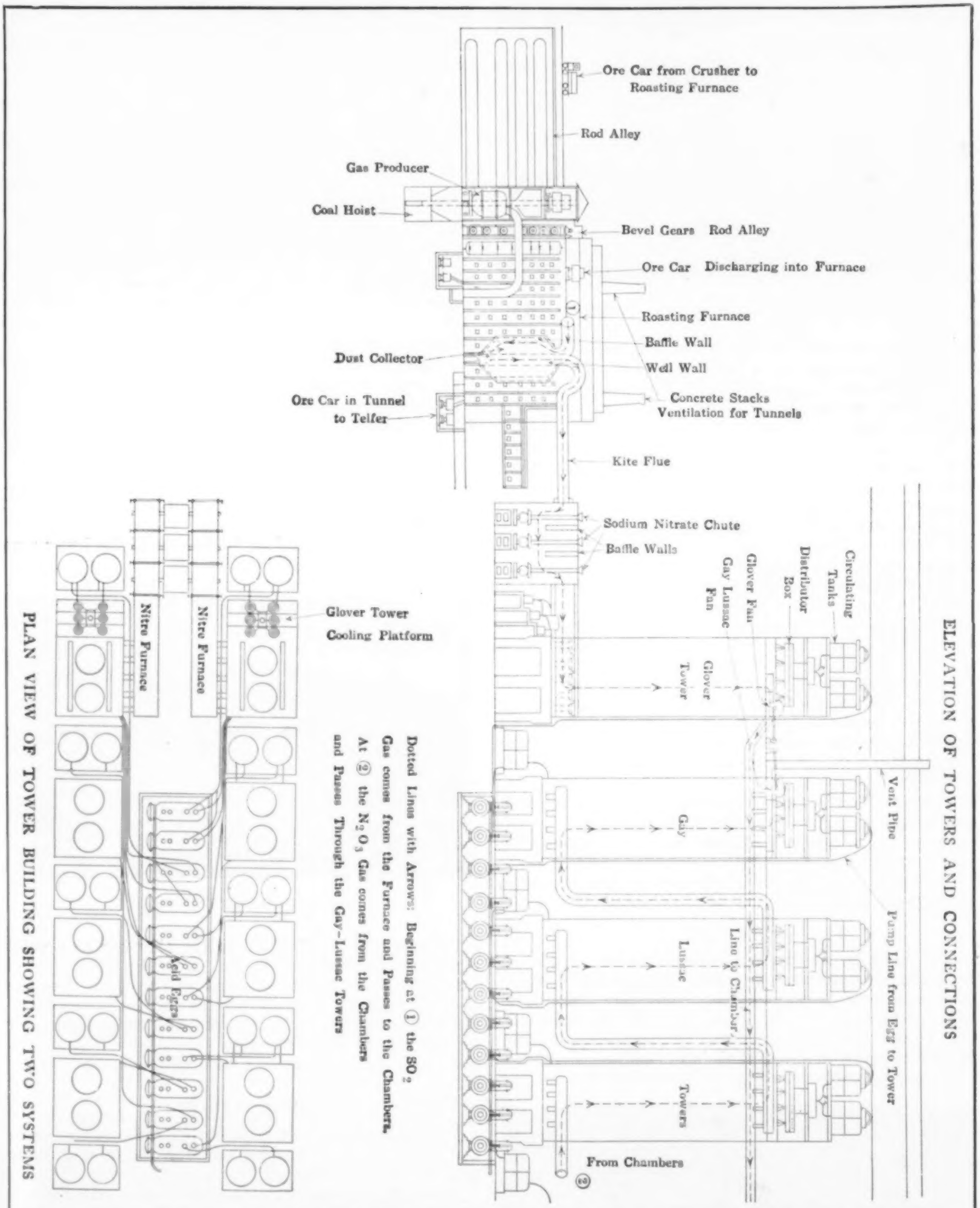
The ore is received from the crusher by an ore car operated on a trestle which dumps into a hopper at the top of the furnace. It is now raked back and forth through the different hearths as it is being roasted by heat furnished by the producer gas method.

Chambers are provided for the admittance of air to the ore as it is being thus roasted which forms SO_2 gas as the sulphur is being liberated in gaseous form in the process. When the ore has been raked on down through



ROASTING FURNACE TUNNEL ROOF SLAB

SITE OF ROASTING FURNACES TAKEN FROM TOP OF 135-FT. CONCRETE STACK OF ROASTING FURNACE TUNNEL



ELEVATION OF TOWERS AND CONNECTIONS

PLAN VIEW OF TOWER BUILDING SHOWING TWO SYSTEMS

Dotted Lines with Arrows: Beginning at (1) the SO_2 Gas comes from the Furnace and Passes to the Chambers. At (2) the N_2O_3 Gas comes from the Chambers and Passes Through the Gay-Lussac Towers

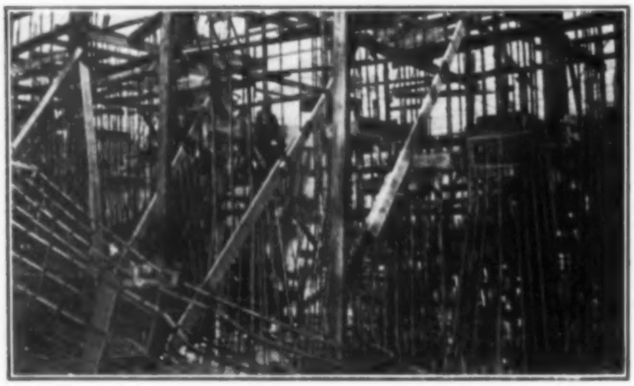
the furnace and reaches the bottom hearth it falls down through a chute into tunnels, one being constructed at each end of the furnace.

In the tunnels ore cars are operated from the chute, which takes the ore out of the furnace to the other end of the tunnel, where it can be loaded to the telpher car and is now ready for the distillation furnaces for the refining of the zinc.

Beginning with the roasting process the plant is divided into three units, each unit requiring four separate buildings, two for the roasters, one for the towers and one for the chambers. Each unit is made up of two systems which is constituted by the following: The roasting furnace equipment as previously described, and one nitre furnace, one Glover tower, Gay-Lussac towers, ten chambers and one storage tank.

ROAST KILNS

These kilns are constructed on a husky concrete foundation, are 80 ft. long, 22 ft. high and 18 ft. wide and



COLUMN REINFORCEMENT ACID TOWER FOUNDATION

built up of red and fire brick, approximately one million 9-in. equivalent brick in each kiln.

The kilns are divided in half by a partition wall, each side having seven arched hearths, three gas chambers and a fire flue.

The buck-staves are thirty-six in number, eighteen on each side of the kiln and connected at top and bottom crosswise of the kiln by two 2½-in. tie rods.

On each buck-staves at the end of the kiln a spring is placed both at the top and bottom so that a long tie rod extending the entire length of the kiln may connect the two springs at the top and the two at the bottom.

All of the buck-staves are firmly grouted in the concrete foundation of the kiln.

The arches for the different hearths and gas chambers are built of tongue and grooved brick block 9 in. x 9 in. x 4 in. and keyed at the sides of the arches with cast iron wedges.

There are gas openings in all of the arches, and the ore slots are placed toward each end of the kiln but on alternate hearths so that the ore being dropped from one hearth is raked clear across the hearth before it will drop to the hearth below.

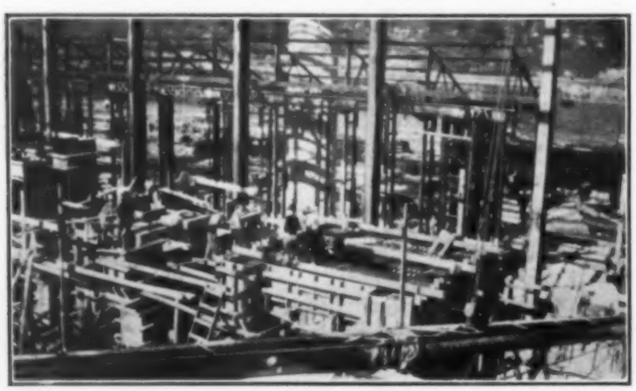
There are two rod alleys and two sets of rods for each side of the kiln, one being placed at each end.

One rake is required for each hearth. After being drawn through on one hearth it is pulled out on a turntable and brought around to the end of the hearth on the same level on the other side of the kiln.

ROD ALLEYS

The rod alley and raking system consists of a large head frame supporting a system of bevel gears which operate an endless chain. These chains are placed level with the bottom of each ore hearth so that the long rods may be operated back and forth by means of a hook on the rod clinging to a large link in the endless chain.

By reversing the gears the rod is pushed through the hearth and coupled to the rake, and by setting the gears in forward motion the rake is drawn through the hearth and when it comes nearly to the end of the hearth the ore drops through the slot in the arch and charges the rake waiting in the hearth below ready to be drawn in the opposite direction from which it was drawn in the hearth above.



ACID TOWER FOUNDATIONS

Thus two rakes are operated at the same time in opposite directions in the same side of the kiln. This roasting kiln and raking system is of the old Hegeler principle with a few modifications.

DUST COLLECTOR

As the SO_2 gas is given off during the process of roasting, it comes out at the top of the kiln and is drawn over to the dust collector through a kite-shaped flue due to a suction created by a large lead fan to be described in connection with the towers.

In this dust chamber is a 3-ft. diameter well wall and eight baffle walls on the sides.

The chamber is of steel plate construction, 20 ft. in diameter, 30 ft. in height, conical in shape at top and bottom, and is lined with 2 in. of asbestos and 9 in. of fire brick.

The purpose of this chamber is to collect the dust from the gas as it falls down during the circulation around the baffle walls.

A drop door is placed at the bottom of the lower cone through which the dust is taken out.

FOUNDATION FOR ROD ALLEYS

The SO_2 gas is admitted to the chamber at a point about two-thirds of its height, is drawn down around the baffle walls, enters the well wall through openings at the bottom, passing up through and out at the top of the well into another kite-shaped flue which leads over the top of the nitre furnace. These kite flues are of steel plate construction and lined with asbestos and fire brick.

NITRE FURNACE

The nitre furnace is built up of red and fire brick and constructed in three parts for the use of three pots and three grates.

There is an opening in the top arch of the furnace directly over each pot for the round chute through which sodium nitrate is poured down into the pot.

A lead pipe connection to each pot from the Glover tower conveys sulphuric acid into the pot. A coke fire underneath the pot heats this mixture forming sodium sulphate and frees nitrous fumes which are taken up by the SO_2 gas as it is drawn over the pots through the flue from the dust collector. This newly formed gas next passes through a brick flue into a four sectional throat flue at the side and bottom of the Glover tower. The nitre furnaces are located in the tower building in the

center at the end between the Glover towers. (See plan of arrangement, page 315.)

ACID TOWERS

The foundations for each acid tower had to sustain a dead and live loading totaling 700 tons; thus they were constructed of reinforced concrete.

A slab, 20 ft. square, 12 in. thick, was built and carried on six 16-in. reinforced beams. This structure was supported by nine columns 36 in. square, the lower 10 ft. of the column was battered $1\frac{1}{2}$ in. per foot, and a footer pad 24 ft. square 24 in. thick formed the base of the whole mass. This reinforcement is shown in the accompanying cut.

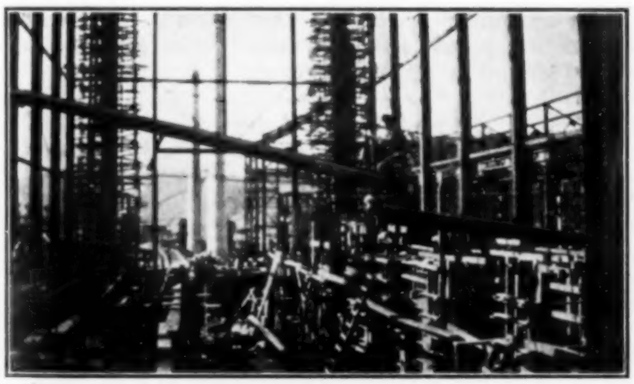
Three-quarter-inch and 1-in. square plain bars were used throughout the work.

The floor slab of the tower was reinforced both ways in top and bottom. No. 1 plain wire was used for stirrups and lacing of the columns.

The towers are entirely lead-lined. In the bottom of the Glover tower the lining was 1 in. thick, weighing 60 lbs. per square foot. The sides of the tower were lined with 30 lb. lead.

Twenty and 30 lb. lead was used for the linings of the Gay-Lussac towers.

The lining of the Glover tower being heavier than the other towers is due to the fact that the temperature is much higher; at times it registers about 150 deg. Centigrade.



ACID TOWER FOUNDATION

The Glover tower which receives the gas from the nitre furnace is called the cooling and concentrating tower, one of which is required to a system.

Three Gay-Lussac towers are required to a system, and they receive the gas after it has made the circuit through the chambers. The towers take the nitre out of the chamber acid as it is pumped up over them after it has made a passage from the Glover tower.

All of the towers are 30 ft. in height above the foundations and 14 ft. square. They are packed with hard-burned chemical brick; about 63,000 used in the Glover tower and throat flue leading to the tower. About 59,000 in each of the two Gay-Lussac towers and 53,000 in the Gay-Lussac tower nearest the chambers. The last 10 ft. in the top of this Gay-Lussac tower is packed with large pieces of 72-hour coke.

The brick used for packing the towers is the size of paving brick weighing about 10 lbs. each, and are laid up in checker formation. The checker openings in the bottom 10 ft. section of the tower were 4 in., the middle section openings were 3 in. and the top section 2 in.

ACID EGGS

The acid eggs are iron castings 2 in. thick, of cylindrical shape, 3 ft. in diameter, 12 ft. long with a flanged

FOUNDATION AND FRAMING FOR SUPERSTRUCTURE FOR CHAMBER BUILDING

head at one end and oval shaped at the other. They are placed on their side and supported on brick piers.

Six eggs are required for each system, and are located in a pit immediately between the two systems of Gay-Lussac towers.

The eggs are connected separately to an air line, and each egg has a separate lead pipe connection with two towers. These pipe lines are fitted with valves so that as the acid drains from one tower into the egg it can be pumped up over another tower.

At the top of the towers are large circular tanks which receive the acid as it is pumped from the eggs. These tanks drain into distributor boxes which in turn outlet into 156 lead pipes which equalize the flow of acid over the square area of the tower.

LEAD FANS

There are two large lead fans, that are electrically driven, to each system.

One fan is located in the line of 36 in. diameter lead pipe connecting the Glover tower with the chambers.

The other fan is in a line of same diameter lead pipe connecting the chambers with the three Gay-Lussac towers. This line leads from the top of the chambers to the bottom of the first Gay-Lussac tower. This tower outlets at the top and another 36-in. pipe connects with the bottom of the next Gay-Lussac tower.

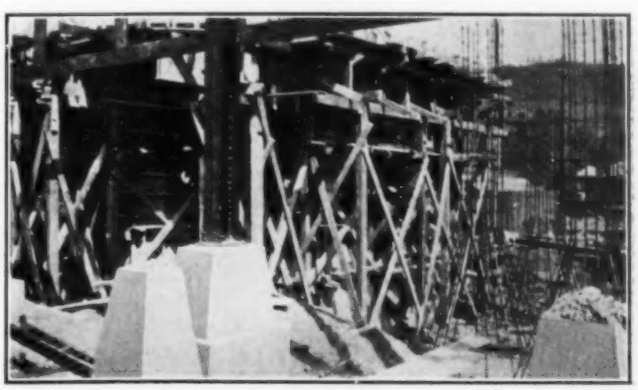
These three towers are connected with each other but not with the Glover tower.

CHAMBERS

The chambers are rectangular in shape, 18 ft. wide, 20 ft. high, and vary from 40 to 60 ft. in length.

The bottoms, tops and sides are made up of 6, 8 and 10 lb. lead.

The chambers are connected with each other and with the towers, one line leading from the Glover tower to



FORM WORK STORAGE TANK FOUNDATIONS

STORAGE TANKS

the chambers and the other line leading from the chambers to the Gay-Lussac towers.

CIRCUIT THROUGH THE TOWERS AND CHAMBERS

Going back to the gas formed in the nitre furnace, the SO_2 gas combined with the nitrous fumes. By the suction of the Glover tower fan this gas is drawn up through the Glover tower and pushed to the chambers. Here steam is admitted to the chambers, and by breaking up with the nitrous gas and the SO_2 a weak solution of sulphuric acid is formed, also a brown gas called nitrous trioxid.

This weak acid is now known as chamber acid which formed in a vapor condensed on the sides of the chambers and dripped to the bottom flowing to an outlet into a line that drains into the egg known as the chamber acid egg.

The nitrous trioxid gas rises to the top of the chambers and the fan on the line with the Gay-Lussac towers pulls this gas into the bottom of the first Gay-Lussac tower up through this tower and on through the other two Gay-Lussac towers.

The weak solution of sulphuric acid is now pumped over the Glover tower, trickling down through the tower washing the SO_2 gas and nitrous fumes which are continually being drawn through by the Glover tower fan from the furnaces.

This chamber acid continues to take up more SO_2 from the Glover tower and drains into tanks on the cooling platform, where the acid is tested for 60 deg. Baumé.

These test tanks are constructed of lead, and contain a coil of lead pipe through which cold water runs continuously.

Until the acid reaches the desired strength it drains from the cooling platform of the Glover tower to the acid eggs, and is pumped up over the Gay-Lussac towers for the nitre to be taken out.

After circulating through these three towers it is again pumped over the Glover tower to receive more SO_2. When the hydrometer registers 60 deg. on the cooling platform the acid is drained into the storage egg, from which it is pumped into large steel storage tanks located at the railroad siding where the tank cars are loaded.

COLUMN REINFORCEMENT STORAGE TANK FOUNDATION

STORAGE TANKS

The storage tanks, six in number, were constructed of 7/8-in., 3/4-in., 5/8-in. and 1/2-in. steel plate with no lining of any kind whatsoever.

The structure was carefully calked as proof against leakage, and was absolutely air-tight. Acid does not attack the steel of the tank without the presence of air.

The tanks are 40 ft. in diameter and 20 ft. in height. Each tank required a foundation good for a loading of 1700 tons. These foundations were of reinforced concrete, the structure consisting of a 20-in. slab 48 ft. in diameter carried on four beams 30 in. wide and 36 in. deep, supported by twelve columns 30 in. square.

The lower 10 ft. at the base of the columns was battered 3 in. per foot. Each column had a footer pad 24 in. thick and 9 ft. square. One-inch-square plain bars were used in the columns, beams and slab. Three-eighth-inch plain rod was used for temperature stress bars and No. 1 plain wire used for lacing the columns.

The buildings of the entire plant are of the latest type of mill structures. They are fireproof in every case; the side walls are built of hollow tile, the framing is all of structural steel and the roofs are of tar paper and corrugated tar felt construction.

The machinery throughout the plant is electrically driven, the power being furnished by a specially designed equipment of the company.

Synthesis of Ammonia

Some interesting experiments on the synthesis of ammonia from nitrogen and hydrogen in their atomic, nascent state, are described in the *Chemical Trade Journal and Chemical Engineering*, Aug. 5, 1916, the data being taken from a communication of Dr. Zenghelis to the Paris Académie des Sciences:

Zenghelis passed, in his first experiments, a mixture of the gases—three parts by volume of hydrogen and one part of nitrogen—through water (acidified with sulphur dioxide in some experiments) in which the catalyst was suspended; the water was heated, but only up to 90° C. Some ammonia was obtained, especially with colloidal palladium or silver as catalysts; but the yields were very poor, and electrolytic and chemically-evolved hydrogen did not give better results. In the second series of experiments the nitrogen was atomic; the hydrogen not. The nitrogen was generated from sodium nitrite and ammonium chloride; this reaction gives free nitrogen and also some nitric oxide and ammonia, which had to be allowed for in the estimates of the ammonia produced. The yields were again very low, although the experiments were continued for more than four hours. In the third series both the elements were in the nascent state, the nitrogen was generated, as in the second series and the hydrogen as in the first, and then decidedly promising results were realized. The temperature ranged from 70° to 99° C.—that is to say, the water was not quite boiling. If all the nitrogen had been converted into ammonia, 5000 cu. cm. of ammonia solution should have been obtained; with spongy palladium 321 cu. cm. were actually found, with colloidal platinum 1755 cu. cm., and with colloidal palladium 1025 and even 2060 cu. cm.; in the last-mentioned case there was more of the catalyst. Thus the yield came up to 40 per cent. The trouble is that the nitrogen was generated from materials as valuable as the ammonia produced.

Recent Developments in Zinc Concentration Practice in the Joplin District, Missouri

BY H. C. PARMELEE

Joplin milling practice has always been unique; not only for its remarkable accomplishments, but also for its deficiencies; as well for the development of interesting local methods as for an apparent disregard of foreign ideas; as much for its independence as for a failure to adopt refinements considered indispensable in other districts. Financially, Joplin milling has been a success; metallurgically it has been at once the admiration and despair of outside engineers—admiration for the success of special methods developed to meet peculiar local needs, and despair at the evident lack of appreciation of some of the finer points in ore-dressing.

But in spite of admitted deficiencies in the past, Joplin mill practice is improving and there are evidences that it is getting on a sounder engineering basis. The newer mills show more attention to the details of classification, regrinding, and the concentration of sand and slime. Efficiency is improved and losses have been recognized and reduced.

One reason assigned for the slowness with which milling has advanced is that mining has been considered more important and has offered the opportunity for quick money-making, even with crude milling methods. Under the leasing system which generally prevails, mining and milling have been done cheaply, but milling has generally been a secondary matter both as to equipment and efficiency, because the time and extent of the leases were limited and soon exhausted. There is no doubt, however, that the time is at hand when more attention is being paid to ore-dressing in the Joplin district in order to prevent waste and increase profit.

Hitherto mills have not been designed on the basis of preliminary tests, such as are made in other places, but they have been erected by contractors who turn over a typical Joplin mill at a fixed price. Operators have followed local custom closely and have been slow to depart therefrom. Perhaps this is because past efforts to improve conditions have been too radical, proposing to revolutionize the whole practice without recognizing the things that Joplin already does well. Those most familiar with local conditions realize that this is not what is needed, but that improvements undoubtedly can be made in important details throughout, and particularly with regard to the recovery of finely ground mineral. Past losses in this respect are indicated by numerous projects for reclaiming fine mineral from old tailing piles and ponds.

Bureau of Mines Studies

An important factor in arousing an interest in better ore-dressing has been the study of local methods conducted by the U. S. Bureau of Mines under the direction of Clarence A. Wright. The reports[1] thus far issued are preliminary to a final document covering the mining and treatment of lead and zinc ores in the Joplin district, based on co-operative work between the Missouri Geological Survey and the U. S. Bureau of Mines. The general result of this work has been to prove definitely the losses sustained in milling and to indicate where and how they may be prevented. Thus it was shown that the average recovery of zinc from the ore, taking the district as a whole, was about 65 per cent, and the deficiencies of jig and table practice were pointed out. The following general outline of the jigging system is given by Mr. Wright.

Outline of Jigging System

"The most common type of jig used in this district is known as the Cooley, similar in principle to the Harz jig. It is of the fixed-sieve type, the water being forced up and down through the screen or grate by the action of a plunger placed in an adjacent compartment. The number and the size of the compartments for each jig depend on the size and character of the ore treated.

"In general, a system of 'roughing' and 'cleaning' is followed in which the feed is given a preliminary cleaning that eliminates the greater proportion of waste material on one or two 'rougher' jigs. The enriched product, which will assay about 14 to 18 per cent zinc, is cleaned on a 'cleaner' jig for the final treatment, bringing the zinc tenor up to 55 to 60 per cent. The 'chats' or included-mineral particles from both the rougher and the cleaner jigs, which together will assay 4 to 8 per cent zinc, are recrushed and either returned to the rougher-jig feed or treated separately over a 'chat' jig. The tailing from the rougher jig is dewatered by means of a dewatering trommel with 1½- mm. to 2-mm. openings, over the outside of which the tailing passes as the trommel slowly revolves. The undersize from this dewatering screen flows to the settling tanks and the oversize to the tailing elevator as waste. The overflow from the tailing end of the cleaner jig, and other jigs if used, also passes to the settling tanks for subsequent treatment.

"The rougher jigs usually consist of five or six cells with a screen or grate area in each cell of 30 by 42 in. to 36 by 48 in. The speed of the shaft connecting the plungers and eccentrics varies from 90 to 120 r.p.m., with the length of stroke of the plungers ranging from ⅜ in. to 1¼ in. The cleaner jigs have six to seven cells with a grate area somewhat smaller than that of the rougher jig. The speed of the shaft connecting the eccentrics and plungers is from 160 to 200 strokes per minute, with lengths of stroke ranging from ⅜ to ¾ in. The chat jigs, which are not commonly used, are smaller and usually consist of four to five cells, and are operated at a higher speed and shorter stroke.

"The material fed to the first cell of the jig is, as a rule, not graded or classified. A bed 5 to 6 in. deep is formed and as a result of the pulsating action of the water the lighter gangue material, such as flint, comes to the surface, the heavier free grains of lead and zinc working to the bottom. The downward suction stroke causes the finer grains of mineral to continue through the screen or grate openings into the hutch of each compartment. The strength of the suction stroke is increased by leaving the gates of the hutch partly open. The accumulation in the hutch is known as 'smittem' and is further treated on the cleaner jig. The bed products of the first two or three cells are also drawn off and pass together with the hutch product to the cleaner jig. The chats or included mineral particles, usually from the last hutch and the last two or three beds, are drawn off and reground before further treatment."

Loss of Fine Mineral in Jigging

A feature of Joplin jigging which always impresses the visitor is the unusual practice of treating an ungraded or mixed feed, ranging in size from ½ in. to dust. Another point is the large amount of water used in transporting the material through the jig. Both of these features undoubtedly contribute to the loss of

[1]Four papers have been written by Clarence A. Wright: *Technical Paper* 41, Mining and Treatment of Lead and Zinc Ores in the Joplin District, Mo.; and separate preliminary papers on Jig Concentration, Table Concentration, and the Possibilities of Flotation.

fine and slime mineral in the jig tailing and have an unfavorable effect on the efficiency of the jig.

Through its investigations on jigging ungraded feed, the Bureau of Mines has shown very definitely by screen analyses and assays that the fine grades are the richest in zinc and cause the greatest losses. Thus in a jig feed of free sheet-ground ore averaging 1.13 per cent zinc, the portion minus 200-mesh amounted to only 3.28 per cent of the whole, but it had an assay value of 5.77 per cent zinc and represented 16.81 per cent of all zinc in the feed. Quite naturally, under the prevailing operating conditions, this fine material largely remained in the tailing, a screen analysis of which showed 3.62 per cent minus 200-mesh material, assaying 4.5 per cent zinc and representing 32.26 per cent of the zinc in the tailing. Even in the dewatered tailing, from which the fine mineral is supposed to have been removed by screening before the oversize goes to the dump, there was 1.09 per cent of material finer than 200-mesh, assaying 4.20 per cent zinc and representing 12.12 per cent of the total zinc going to the dump.

This condition of slimy feed is emphasized even more strongly in the case of a "chatty" ore, where the mineral is not so free as in the preceding case. Where the average jig feed of such an ore assayed 1.99 per cent zinc, there was 12.43 per cent of material finer than 200-mesh assaying 2.25 per cent zinc and representing 14.13 per cent of the total zinc in the feed. The jig tailing before dewatering contained 10.03 per cent minus 200-mesh material assaying 1.45 per cent zinc and representing 16.7 per cent of the total zinc in the tailing. The dewatered tailing contained 3.79 per cent of material finer than 200-mesh, assaying 1.4 per cent zinc and representing 6.5 per cent of the total zinc lost.

These examples are typical of general conditions and point clearly to one source of preventable loss. An obvious remedy is to deslime the jig feed, thereby immediately removing part of the pulp suitable for table concentration and leaving a clean coarse feed for the jig. Another reason for desliming before jigging is that the screening of jig tailing for recovery of fine mineral is quite inefficient.

Inefficiency of Screening

A typical example will be taken from the Bureau of Mines report, with reference to a 1.5-mm. screen.

$$\text{Efficiency} = \frac{\text{Weight of undersize passing through screen}}{\text{Total weight of undersize in feed to screen}}$$

Screen Product, Size Opening	Screen Feed, per Cent	Screen Oversize, per Cent
Over 1.5 mm	80.1	87.5
Thru 1.5 mm	19.9	12.5
	100.0	100.0

$$\text{Weight of undersize in the oversize} = \frac{80.1 \times 12.5}{87.5} = 11.44$$

$$\text{Screening efficiency} = \frac{19.9 - 11.44}{19.9} = 42.51 \text{ per cent.}$$

The method of handling chats or middlings, material requiring regrinding in order to free the included mineral, is not as logical or satisfactory as could be desired. Local custom dictates regrinding with rolls and generally a return of the product to the jig of origin. In some cases the more logical step is followed of retreating the reground product over a separate jig. The latter plan offers a number of advantages, for the chats are an enriched product which will yield a higher recovery if treated separately than when mixed with original feed of lower grade. Further, separate treatment avoids the addition of more fine material to the rougher jig which, in the absence of desliming, is already overburdened with fine and slime material.

Table Concentration More Widely Practised

The concentration of sand and slime pulps by reciprocating tables has shown a marked improvement in the Joplin district in the last few years. The number of tables in use in a mill has increased, so that table capacity is more nearly proportionate to the tonnage to be treated. In accounting for the deficiencies of table concentration in Joplin it must be recalled that the operator has bent his efforts toward coarse concentration on jigs and has done as little fine grinding as possible. In times past it has been even a matter of pride with some operators to have as few tables in the mill as possible, in some cases none at all. In contrast to this condition is the present tendency toward better classification, provision for uniform table feed, and more extensive and efficient tabling. As in the case of jigging, more attention is being paid to regrinding middlings, with treatment on separate tables instead of returning to the table of origin.

Table I.—Results of Tests of Table Sections in Various Mills.

Test No.	Number of Tables in Operation	Zinc Content of Feed to Tables, per Cent	Zinc Content of Concentrates Produced From Tables, per Cent	Zinc Content of Tailings From Tables, per Cent	Percentage of Zinc Recovered	Character of Ore Treated
1	1	6.35	58.0	3.75	43.8	Chatty
2	1	4.90	50.2	1.50	71.2	Free
3	2	2.95	55.6	1.35	55.5	Chatty
4	2	4.85	57.4	1.70	67.0	Chatty
5	2	4.70	57.0	1.55	69.0	Chatty
6	2	3.12	54.5	1.00	69.1	Chatty
7	2	4.30	56.2	1.35	70.2	Chatty
8	2	5.65	57.1	1.62	73.5	Free
9	2	7.75	57.2	2.25	73.9	Free
10	3	3.75	52.8	1.20	69.5	Chatty
11	3	6.75	54.6	1.55	79.4	Free
12	5	4.65	42.0	1.30	74.3	Chatty
13	6	3.95	59.3	1.19	71.3	Free
14	7	4.65	55.0	1.42	71.3	Chatty

Table feed is made up mainly of the fine material separated from jig tailing as it passes over the dewatering screen at the end of the jig. This pulp flows to settling boxes from which it is later pumped to the classifiers and tables. In some cases a sand-slime separation is made mechanically, as with Dorr classifiers, after which the sand is hydraulically classified into several products and the slime thickened in Dorr thickeners prior to tabling. Flotation is being adopted in some instances for the treatment of slime tailing.

The efficiency of table concentration varies with the ore, *i.e.*, whether "free" or "chatty," being higher for the first type and lower for the second. From the detailed study made by the Bureau of Mines, previously mentioned, we select Table I to illustrate this point.

Slime Losses in Table Concentration

Losses in table concentration as determined by screen analyses and assays of tailings show plainly the detrimental effect of slime; and this, in turn, suggests the need of better classification to relieve sandy pulps from minus 200-mesh material. In a study of six tables treating a classified pulp, two of them handling slime finer than 200-mesh, the percentage of that grade in the feed to each table ranged from 9.7 to 91.2, and the loss of zinc in the tailing was contained, for the most part, in that size. Owing to poor classification the pulp going to sand tables contained too much slime, while the slime tables were handicapped by receiving too thin a pulp. The average zinc content of feed to all tables

was 3.95 per cent; of concentrates from all tables 59.3 per cent; of tailings from all tables 1.19 per cent; average percentage recovery 71.3. A screen analysis of total tailings from the six tables showed that 15.5 per cent of the material was minus 200-mesh, assaying 5.07 per cent zinc and representing 65.78 per cent of the total loss in tailings. These results were obtained on a "free" ore; similar tests on a "chatty" ore showed the necessity of regrinding middlings.

From these tests it is apparent that still further improvement can be made in Joplin table practice by proper classification and sizing, suitable pulp density, retreatment of middlings and mixed products, and attention to the details of table operation. The newer mills are embodying many of these improvements, as will be pointed out later in a descriptive article. Further improvement will come as technical knowledge is disseminated and its benefits appreciated.

Possibilities of Flotation

In view of the evident importance of the slime problem in Joplin, flotation is naturally considered as a solution. A number of mills are now using this process in an experimental way with considerable success. At least one flotation plant has been built to retreat an old dump and other similar plants are in prospect. The Bureau of Mines studied this phase of Joplin milling and made a number of practical tests.

The comparatively small capacity of Joplin mills and short life of the leases make it necessary to consider the quantity of material that might be available for flotation and the economy of installing a special plant for its treatment. Owing to the varying character of the ores, the amount of fine material produced in crushing is not a constant for all mills. Taking 65-mesh (0.208 mm.) as a dividing line, screen analyses of tailings from several mills showed that the percentage of material passing that mesh ranged from 3 to 16, according to the ore and fineness of original crushing. Soft-ground ore yielded more fine material than sheet-ground, but the finest sizes of the latter showed a higher zinc assay than the former. If the mineral in material passing 35-mesh (0.417 mm.) should prove fine enough for flotation, it would appear that a sheet-ground mill of 300 tons capacity would produce about 15 tons of flotation feed per day, and this is considered about the smallest tonnage that would warrant an installation. It might be found profitable to regrind part of the sand tailings in order to supply a suitable tonnage. The economy of the whole proposition would depend on the grade of the material, cost of operation and the market for concentrates.

Actual experiments by the Bureau of Mines on the flotation of Joplin zinc slime showed that "it is fairly easy to float the sphalerite from the gangue by using warm solutions and about 1 lb. per ton of any suitable oil, either from wood or coal distillation, and that acidity, although it does not seem to be necessary, allows the froth and tailings to separate more quickly. Cold solutions gave as high extractions as warm solutions, but the grade of the concentrates was not as high.

"A scheme making use of rougher and cleaner units of flotation cells seems essential in order to get a high extraction and concentrates of acceptable grade.

"In the experiments made in Joplin, the thickness (ratio of solids to water) of the pulp treated ranged from 1:3 to 1:7. In practice the most favorable ratios for different ores would, of course, have to be determined by experiment.

"In general, a mixture of sand and slime requires a denser pulp, whereas for a mixture consisting wholly of slime (finer than 200-mesh) a thinner pulp is desirable. Thickening of the slimes from the Joplin district mills would be necessary, and could be accomplished by the use of Dorr thickeners or some other device that would give the flotation machines a uniform feed of constant thickness.

"The addition of acid may not be absolutely essential for all the ores of the Joplin District, although the local tests showed that a small quantity of acid was of great help, especially in cleaning the concentrates."

Flotation will undoubtedly prove a profitable accessory process in Joplin mills, and its introduction should be encouraged in an experimental way until its peculiarities are understood. If the possible improvements in jigging and tabling are carried out as indicated earlier in this article, there may not be the field for flotation at some mills which now are in need of a method of reducing slime losses. On the other hand the larger mills are likely to find a place for the process, while for retreating old dumps and slime ponds it is almost certain to be used to advantage. At the present time the Joplin district is regarded as offering opportunities to trained metallurgists who can see and improve the weak points in present practice; at the same time it is good advice to prospective reformers to study local conditions carefully, accept the successful features and make haste slowly in adopting radical changes.

The Effect of Corrosion on the Ductility and Strength of Brass*

BY PAUL D. MERICA.

Investigation[1] of the last few years has established the fact that brass will crack or fracture when exposed to the action of corroding agents, while at the same time under tensile stress, even when the value of this stress is much less than the ultimate strength or even the yield point of the material, as determined in the tensile test.

It is well known that surface corrosion plays an important part, even a necessary one, in the "season-cracking" of brass, and Jonson[2] has carried out a number of experiments, in which he has subjected brass test specimens to tensile stress in a testing machine, the specimens being at the same time immersed in a solution of concentrated ammonium hydroxide. He found that so long as the applied stress in these tests was not greater than the elastic limit of the material, the specimens did not fail, but when a stress was applied greater than this limit, *e.g.*, from 20,000 to 40,000 lb. per square inch, cracks would appear after a few days, the specimen would yield continually and finally break.

The effect of corrosion, at least of that caused by the action of ammonium hydroxide, on brass under stress, be it initial or due to external load, is to decrease the strength and also the ductility of the material, for it is a striking feature of such brass failures as occur, due to combined stress and corrosion, that they occur with little elongation; the brass does not display its usual ductility.

Parallel to his stress-corrosion tests, Jonson ran tensile tests on specimens of the same materials, subjecting them to the same loads, but not at the same time to the

*To be published also as a Technologic Paper of the Bureau of Standards.

[1]E. Heyn, Internal Stresses in Cold-wrought Bars, and Some Troubles Caused Thereby. Journ. Inst. Metals, Vol. XII, 1914, p. 3.
A. D. Flinn, Brass in Engineering Construction, Engineering Record, Vol. 68, 1913, p. 527.
P. D. Merica and R. W. Woodward, The Failure of Structural Brass, Trans. Amer. Inst. Metals, 1915.

[2]E. Jonson, Failures of Forgible Brass Bars, Trans. Amer. Inst. Metals, Vol. VIII, 1914, p. 135.
The Fatigue of Copper Alloys, Proc. Amer. Soc. Test. Materials, Vol. XL, 1915, p. 101.

action of the ammonium hydroxide; such specimens did not fail after months of test.

Furthermore, specimens were corroded with ammonium hydroxide and subsequently tested in tension, giving quite normal results, such that it must be considered that it is the simultaneous effect or action of tensile stress and corrosion (ammonium hydroxide), which produces failure in brass at stresses below its ultimate strength.

It may here be noted that Jonson used only ammonium hydroxide in his tests; he draws, however, the conclusion that any corroding agent, even water, will in time produce the same effect of cracking. The admissibility of this further conclusion seems probable, but is not to be regarded yet as proven.

The author wishes to advance an explanation for this rather striking phenomenon, of the combined action of tensile stress and corrosion on brass, indicating the actual manner or "mechanism" by which this effect is produced, in the hope that this explanation will contribute to progress in dealing with this important technologic problem.

The initial effect of corrosion on any metal, stressed or unstressed, is to roughen the surface, such that in section it appears with ridges or furrows. This non-uniform action of the corroding agent is due to slight variations of the electrolytic (solution) potential over the original (smooth) surface; in the case of a non-homogeneous alloy such as an alpha-beta brass—type, 60 per cent copper and 40 per cent zinc—a difference of potential would in general exist between the alpha and the beta constituents. If the corroded bar were under tensile stress, the value of the fiber stress at the surface would, theoretically at least for a long bar, be the same at all points; this can no longer be true, however, of the roughened surface.

Leon[3] has shown that the stress at the bottom of a semi-circular notch, in a tensionally stressed bar, is twice that of the average stress for the section, and that for sharper notches the stress might, at least for hard rubber, be as much as five times the average stress. The stress at the free edges of the notch is under such circumstances practically zero. The fiber stress along the roughened surface will, therefore, vary in value between zero, at the tops of the small ridges, and a value, at the bottom of the furrows, much larger than that of the average stress.

Now the electrolytic potential of a metal or alloy is increased[4], *i.e.*, made more electropositive, by the application of a stress; the results of some measurements and further discussion of this effect of stress on the solution potential will be given later on.

It is therefore evident that after the formation of the furrowed or roughened surface on the brass specimen under tension, the e.m.f. will be greater at the bottom of the small nicks or notches than on the side of these notches immediately adjacent. Other things being equal, corrosion will therefore be more severe at the bottom of these notches than elsewhere, and the notches will grow inward, becoming sharper and sharper, quite in contrast to their behavior when uncorroded, since in a ductile material such notches tend to flatten or smooth out under tension, thus reducing the local fiber stresses at these points.

In fact, Heyn[5] finds that the behavior of a notch in a bar under tensional stress distinguishes brittle from ductile material. The notch in a ductile material tends to smooth out, whereas in the brittle material it becomes sharper and narrower under tension, finally causing fracture Thus the effect of corrosion under stress is to favor the growth and narrowing down of cracks and to cause an apparent brittleness of the brass.

MEASUREMENT OF THE ELECTROLYTIC POTENTIAL OF BRASS UNDER STRESS

The increase of electrolytic e.m.f. of a simple metal to a solution (containing ions of the same metal) due to the application of a stress may be calculated[6] from the consideration that the increase of e.m.f. of a system is proportional to the increase of free energy, and that for isothermal, reversible processes the increase of free energy of a system is equal to the amount of work done on it.

The application of stress of values below the true elastic limit is a reversible process and can be carried out isothermally

Considering, for the purpose of simple and approximate calculation, that brass is a simple metal of equivalent weight equal to

$$\frac{63 + 65}{2 \times 2} = 32$$

a stress of 25,000 lbs. sq. in., applied isothermally to a brass rod, having a modulus of elasticity of 15×10^6 lbs. per sq. in., and a density of 8, should produce an increase of e.m.f. equal to

$$\frac{\text{work (in ergs)}}{\text{density}} \times \frac{\text{equivalent weight} \times 10^{-7}}{96{,}500}$$

$$= \frac{\dfrac{25{,}000}{2} \; \dfrac{25{,}000}{15{,}000{,}000} \; \dfrac{1{,}000 \times 980}{14.2} \times 32 \times 10^{-7}}{96{,}500 \times 8}$$

$= 0.000006$ volts.

With greater stresses and after plastic yielding had commenced, an increase of 2 millivolts might be obtained, assuming that one-half of the energy of deformation is potentialized.

Some measurements have been made of these quantities, with, however, contradictory results.

Hambuechen (loc. cit.) finds for brass—composition of the brass and of the electrolyte not stated—an increase of 0.3 millivolts at the elastic limit, and an increase of about 4 millivolts at the point of rupture. For iron and steel he finds much larger values.

Both Walker and Dill and Richards and Behr, on the other hand (loc. cit.) come to the conclusion that, although there is an increase in the e.m.f. of iron (they did not work with other metals) caused by application of stress up to and beyond the elastic limit, it is so small as to defy measurement. They explain Hambuechen's results on iron as having been due to the hydrolysis of the ferric salt, which he used as electrolyte.

In the measurements made by the author use was made of two electrodes of the same material, and in the same condition. One of these could be stressed, the other served as a comparison electrode, measurement being made in each case of the difference of potential between the two.

These were immersed side by side, in a solution contained in a large glass tube, with stopper at the bottom, the solution being contained between a layer of paraffin below (to which was sometimes added a slight amount of carbon tetrachloride) and a layer of a transformer oil above These precautions were taken to prevent oxygen from the air from affecting the e.m.f.

[3]Leon, Über die Spannungsverteilung in einer halbreisförmigen Kerbe, Österreichische Wochenschrift für den öffentlichen Baudienst, Vol. 29, 1908, p. 43.

[4]C. Hambuechen, The Corrosion of Iron, Bull. Univ. Wisconsin, 1900, No. 8.

T. Richards and Behr, The e.m.f. of Iron Under Various Conditions, Publ. Carnegie Inst., 1906, No. 61.

[5]E. Heyn, Materialienkunde, p. 376.

[6]Walker and Hill, The Effect of Stress on the e.m.f. of Soft Iron, Trans. Amer. Electrochem. Soc., Vol. VII, 1907, p. 153.

The arrangement is shown in the sketch, Fig. 1. The potential measurements were made by a potentiometer. It was found necessary to protect the electrodes from light during measurements by wrapping black cloth around the container.

The material used in the tests was a homogeneous alpha brass of the following composition:

Copper	67.5 %
Zinc	32.5 %
Tin	——
Lead	0.06%
Iron	0.02%
Manganese	——

which was most kindly furnished by the American Brass

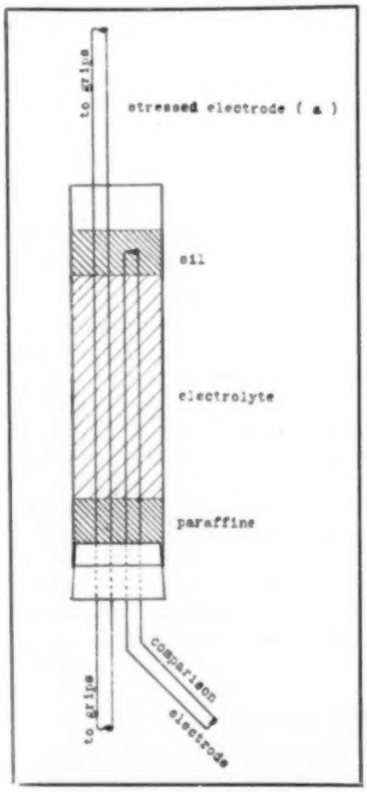


FIG. 1—DISPOSITION OF ELECTRODES

Co. in the form of ¼-in. rods. Before the tests, this material was annealed at 400 deg. C. for an hour in order to relieve any initial stress, and the surface thereupon prepared by light rubbing with fine emery paper, followed by etching with nitric acid, washing and drying.

The test procedure consisted in placing the specimens in position, with the electrode (a) under zero stress, noting from time to time the e.m.f. between (a) and (b), then applying a stress, in units of 10,000 lb. per square inch, again noting during a certain period of time the

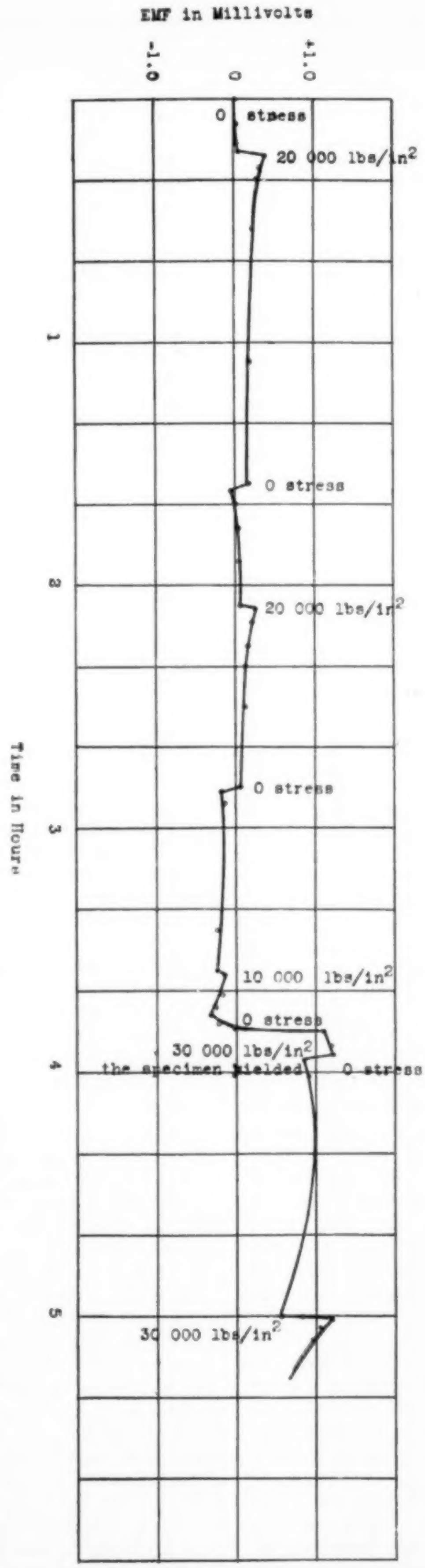


FIG. 2—THE E. M. F. OF STRESSED TO UNSTRESSED BRASS IN A SOLUTION OF N/10 $CuSO_4 \cdot ZnSO_4$.

The + sign indicates that the bar under stress is electropositive to the comparison electrode.

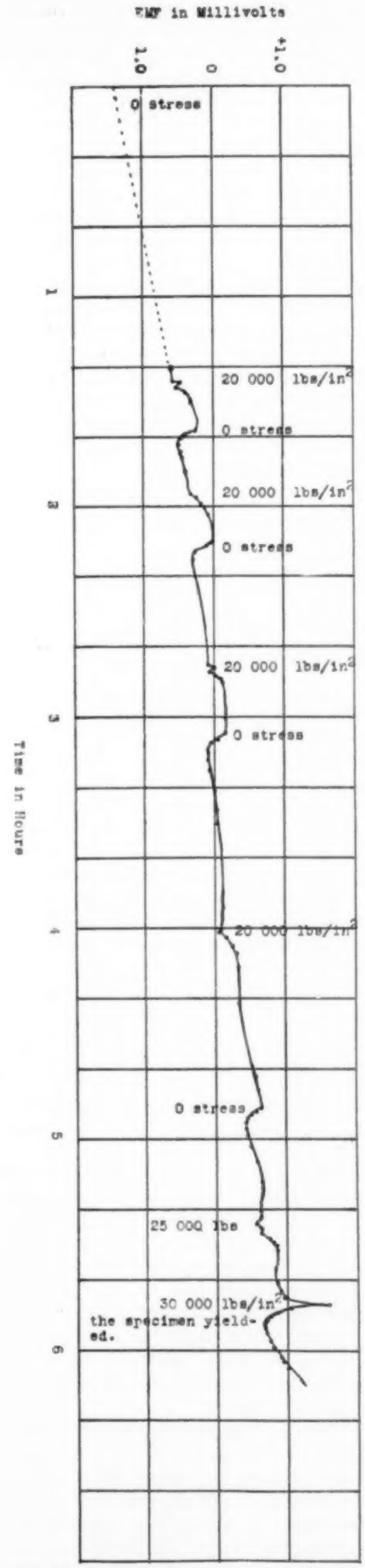


FIG. 3—THE E. M. F. OF STRESSED TO UNSTRESSED BRASS IN A SOLUTION OF N $ZnSO_4$.

The + sign indicates that the stressed bar is electropositive to the comparison electrode.

e.m.f., removing the stress, noting the e.m.f., reapplying the stress, etc. The results of these measurements are best studied in the form of a curve, giving the e.m.f. as a function of the time, a change of stress being noted on the curve. Two such curves showing typical results obtained are given in the Figs. 2 and 3.

It is seen that there is a small but unmistakable increase in the e.m.f., due to the application of stress, and that this becomes relatively quite large, in Fig. 2, when the yield point of the brass is reached.

It is now to be noted that when a bar of metal is subjected to a tensile stress, a lowering of temperature takes place, and this lowering of temperature itself produces a momentary change in e.m.f., which often masks the permanent one. This effect can be noticed in the curves, and it is for this reason that the author adopted the method of holding the specimen at a constant stress for some time, and noting the e.m.f., instead of using Hambuechen's method of continually increasing the stress during the course of the measurements.

CONCLUSIONS

It is believed that an increase in e.m.f. of alpha brass to solutions containing zinc and copper ions, caused by the application of tensile stress, has been indicated and measured. This amounted to about 0.2 millivolts for 20,000 lbs. per square inch (below the elastic limit) and to about 1 millivolt at the yield point of the material, 30,000 lb. per square inch.

This value is apparently much greater than would be calculated for elastic stresses from thermodynamic considerations. It agrees well with values calculated for stresses above the elastic limit. The author does not wish at present to discuss this divergence, otherwise than to point out that the e.m.f. measured may be that at some point of the surface, e.g., at the bottom of a small notch, where the fiber stress is much greater than the average. In that case these results could be brought into agreement with thermodynamic theory.

An explanation is given of the effect of corrosion on brass under stress, in decreasing the ductility and strength, and which is based upon this fact of the increased e.m.f., and therefore corrodibility of brass under stress. At the bottom of small furrows in the roughened surface the stress is greater than at ridges immediately adjacent; a galvanic couple is formed, and the bottom of the furrow only is corroded, forming in time a crack, which becomes narrower and sharper as it penetrates inward, finally so reducing the cross section that fracture occurs.

This conception of the cause of the embrittling effect of corroding agents on brass under stress is borne out by the examination of samples which have been subjected to Jonson's test. In such samples not one but several fissures appear, narrowing down and becoming microscopically fine as they penetrate farther and farther into the interior of the specimen.

It may be noted in this connection that these fissures appear to favor the beta constituent and to avoid the alpha in a brass, such as manganese bronze, containing both of them.

The question as to why brass should be so susceptible to this effect and not also iron and steel (apparently at least) cannot at present be adequately answered, not indeed until further investigation has considerably increased our knowledge concerning the values of the stress-e.m.f. effect in these materials, the relative significance of this effect in comparison with other local e.m.f.'s (due to oxide and slag inclusions, etc.), the effect of the covering of corrosion product formed, and other points.

Other things being equal, the effect produced by a corroding solution having a low conductivity will apparently be greater than that of one of high conductivity, since is allows greater prominence to those local stress e.m.f.'s between portions of the material immediately adjacent; it is known, for example, that nitric acid does not produce cracking in initially overstressed brass in the manner in which ammonium hydroxide or mercurous nitrate or chloride does.

Bureau of Standards,
Washington, D. C.

Blast Furnace Products

BY J. E. JOHNSON, JR.

The products of the blast furnace may be divided into four broad classes, which in the order of importance and tonnage produced are steel-making irons, foundry-irons, puddling irons, and ferro-alloys. These classes are each subdivided into several subclasses. Steel-making and puddling irons and ferro-alloys depend entirely upon their analysis in the ordinary elements for their qualities, but foundry irons are required to have certain physical properties also. These physical properties, as will be shown presently, depend upon their content of certain elements for which we have only recently begun to analyze, and, therefore, their qualities are commonly not specified in terms of analysis in these elements, but in terms of analysis in the ordinary elements and physical properties combined. These relations are complicated and difficult; they require an article to themselves, therefore, the present article will be confined to the description of the other three classes of furnace products.

The Controlling Elements

The elements which are always present to some extent and whose quantity controls the qualities of iron as regards chemical specifications, are the same as those given in the article on "burdening," silicon, sulphur, phosphorus, manganese and carbon. In addition to these elements, there are present occasionally other elements, chromium, nickel, arsenic, etc.

In some of the earlier works on metallurgy, analyses of pig-iron were given showing appreciable quantities of calcium, aluminium and magnesium, but it seems safe in the light of our present knowledge to say that these were reported in error, since it is now absolutely certain that these elements are none of them reduced, or at least dissolved in the iron, by the action of the blast furnace.

Steel Making Irons

These may be broadly subdivided into two classes—acid and basic, so-called from the fundamental nature of the steel-making process in which they are applied.

In the acid processes, the lining of the steel-making vessel is silicious, and no bases such as lime or magnesia can be added to the charge because the presence of such bases would result in scouring out the acid lining of the furnace. The phosphorus cannot be removed except in the presence of a strongly basic slag, and these processes consequently do not remove any of the phosphorus in the original charge. Therefore, the phosphorus in the pig-iron must not only be as low as the desired phosphorus content of the steel, but must actually be lower because the phosphorus all remains while the other metalloids are almost wholly removed, and some of the iron is oxidized and lost in the slag during the conversion process, so that the weight of the steel produced is less by several per cent than that of the iron charged, and the constant quantity of phosphorus accordingly becomes a higher percentage of this reduced weight.

In the basic steel-making processes, on the other hand, the lining of the vessel is made of basic or neutral ma-

terials so that basic fluxes in sufficient amount may be added to the charge, and by the presence of these, the phosphorus may be removed down to almost any limit desired.

The maximum limit for phosphorus in any ordinary steel is 0.09 per cent, and, therefore, the maximum phosphorus in acid steel-making iron is about 0.08 per cent. In many varieties of steel, the allowable phosphorus is much lower and the phosphorus in the iron must be correspondingly lower.

In basic steel-making irons, on the other hand, the phosphorus may theoretically rise to any percentage without preventing the conversion of the iron into good steel, and actually does rise to 2 per cent and over in some steel-making irons in regular use in European practice.

No attention is paid to the carbon in any steel-making iron, either acid or basic, and it need not be mentioned again in connection with these irons.

Irons for Acid Steel Making

The three principal varieties of this are standard (acid), bessemer, acid open-hearth and "baby" bessemer.

Standard Bessemer

Up to a few years ago the acid bessemer process was the predominating process for the manufacture of steel in this country, but about twenty years ago the basic open-hearth process began to assume greater and greater importance until now bessemer steel is relegated to a bad second in the race. Practically all rails were formerly made of bessemer steel, but the superior quality which can be obtained with open-hearth steel has forced the abandonment of bessemer material for this service, and bessemer rails now made are only an insignificant portion of the total rail tonnage. The principal uses left for bessemer steel are for the manufacture of welded steel pipe, for which it is distinctly better than open-hearth, and sheet bar for rolling into tin plate. Some bessemer billets for drawing into wire are also made. The phosphorus specifications in these different classes of material vary, but normally the upper limit is 0.09 per cent so that the upper limit for the pig-iron for conversion into this steel is about 0.08 per cent. In some special cases higher phosphorus than this is permitted, and in many other cases somewhat lower phosphorus is specified.

SULPHUR SPECIFICATIONS

Sulphur, like phosphorus, is not removed at all by the acid processes, and, therefore, the sulphur in the pig-iron must be somewhat lower than the amount desired in the steel for the same reason as given for the phosphorus. As a general thing the sulphur specification for standard bessemer iron is under 0.05 per cent. It generally averages somewhat below this in good practice, while in some cases the steel makers desire it somewhat higher, though not much is said about this because sulphur has deservedly a bad name in the metallurgy of iron.

SILICON SPECIFICATIONS

The silicon in standard bessemer ordinarily runs from 1 to 1.5 per cent. This depends somewhat upon the bessemer practice and the class of steel being made. A certain amount of silicon must be present to give the heat required in the bessemer blow, while too much leads to excessive blowing time and too hot steel.

MANGANESE

The manganese requirements of standard bessemer are not very strict. Iron can be successfully used running very low in this element, and it can also be used up to 1.5 per cent or even higher, but the manganese burns out during the blow, and combining with the silicon makes a very thin slag, the effect of which is to produce what the steel men call "sloppy heats," and manganese is not desired much above 1 per cent on this account. On the other hand, there is a growing belief in the steel business that the best steel cannot be made without the presence of a certain amount of manganese to prevent over-oxidation of the iron, and it is doubtful if an iron running 0.25 manganese, in the long run, would produce as good steel as one running 0.75 per cent.

Iron for the Acid Open-Hearth

The quality of the product of the acid open-hearth furnace is in some way not fully understood better than that of the basic open-hearth for some purposes. Special forgings, springs, and especially steel castings can be made to much better advantage from this material than from the basic open-hearth, so it is considerably used in spite of its higher cost. In particular material of this kind the phosphorus specifications are always low, generally around 0.04, and not to exceed 0.05. The iron for this process, therefore, must be down to about 0.03 or 0.035 in phosphorus to make the class of steel desired.

SULPHUR

The sulphur in this class of steel must always be kept low, usually below 0.04 per cent, and for this reason the sulphur in the iron must practically be no higher than the phosphorus, 0.03 to 0.035 per cent.

SILICON

The silicon specifications for this material are about the same as those for standard bessemer. The amount desired varies according to the practice and the conditions. Sometimes it goes as high as 2 per cent, but too much silicon requires a greater length of heat, and is, therefore, not desirable.

MANGANESE

Manganese specifications are not commonly given for this class of material. The considerations which control are very similar to those in the bessemer process, but the danger from sloppy heats does not exist and, therefore, the manganese can go somewhat higher than the acid open-hearth without being objectionable.

Iron for the "Baby" Bessemer

This process is only used in the production of steel castings, especially those of small size, and for this purpose the steel must be very hot in order to pour well into small moulds. Large heats of steel cannot be handled because it would be impossible to pour them quickly enough into a great number of small moulds, therefore, the bessemer vessel used is a small one, normally of about two tons capacity. In order to obtain the high temperature necessary, the converter is almost always side blown instead of bottom blown. Phosphorus specifications are practically the same as in the acid open-hearth, 0.04 or 0.05 and under. The loss is considerably heavier in this process than in the acid open-hearth, and, therefore the phosphorus tends to rise much more in the conversion so that the phosphorus in the iron must be at least as low as in the acid open-hearth, 0.03 or 0.035 per cent and under.

SULPHUR

The sulphur specifications for this iron have to be more rigid than those for the acid open-hearth because the iron must be melted in a cupola for introduction into the converter, and always picks up an objectionable quantity of sulphur in this remelting so that it is very difficult for the steel founder to meet the rigid sulphur specifications without having a very low sulphur iron to begin with. Therefore, iron for this process is desired

0.025 or under in sulphur, though it may be accepted as high as 0.035.

SILICON

In order to give the high temperature desired, iron for this process must have a high silicon content, never less than 2 per cent, and ranging up to 3 per cent and over. The burning of this silicon in the converter supplies the heat necessary to bring about the high temperature desired.

MANGANESE

There are no manganese specifications for this iron. Much of it is made and used very low in this element, being made from magnetite ores, but it is extremely doubtful whether this is as desirable as an iron containing a considerably larger quantity of this element, for the reasons already given.

Iron for Basic Steel Making

The basic processes for making steel are in a broad way similar to the acid processes except as to the character of the vessel-lining used, the vessels used being the bessemer converter and the open-hearth furnace as in the acid processes. The "baby" bessemer is not used with a basic lining for reasons not pertaining to the blast furnace, so they need not be discussed here.

When a basic lining is used, a condition is brought about altogether different from that involved in the use of the acid processes. In the latter the presence of silica, caused by the oxidation of the silicon in the iron, makes no difference because the lining of the vessel being acid, this silica has no effect upon it, but in the basic process this silica attacks vigorously the basic lining of the vessel even in spite of the bases added to the charge. The more silicon there is in the iron, the more silica is produced, and the more extensive is the damage done by its inroads on the lining, therefore, the first consideration in irons for basic steel making is that the silicon shall be low. This, however, brings about other conditions, especially in the basic bessemer.

The heat necessary to raise the temperature of the molten iron to that of molten steel, some 400 degrees F., is derived principally from the oxidation of the silicon since the oxidation of carbon to CO, the chief product of its oxidation in the converter, generates but little heat above that required for heating the products of combustion, and the nitrogen which accompanies them, to the necessary temperature. A greater amount of heat is required in the basic bessemer process than in the acid, and when we lower the silicon our principal fuel for the production of this heat is discarded; this must, therefore, be made up by other fuels. The only ones available commercially are phosphorus and manganese, consequently irons for the basic bessemer process require phosphorus to the extent of 2 per cent or over, or when this is not available, manganese can be substituted for it to some extent. This process for making steel is not in use in the United States, and complete data concerning the latest practice in regard to it are not available.

Iron for the Basic Open-hearth Process

The principal specifications in regard to this iron are those in regard to silicon and sulphur.

SILICON

This element is always desired below 1 per cent for the reason already explained, and the universal specification for merchant iron of this kind is silicon 1 per cent and under, but when the steel works operate their own furnaces, they take iron running as high as 1.20 in silicon. In general, however, the iron supplied to the basic open-hearth furnaces average about 0.75 to 0.90 per cent silicon. It is not produced to average much lower than this because with this amount the destruction of the furnace linings is not very severe, and it is practically impossible to produce regularly iron with lower silicon without either increasing the sulphur or the coke and limestone consumption of the blast furnace.

SULPHUR

The universal specification for merchant basic iron is sulphur under 0.05 per cent. Steel works take iron from their own furnaces up to 0.06 per cent. Part of the sulphur is removed by the basic slag, and there is no difficulty in making steel with sulphur 0.03 and under out of iron with sulphur 0.06. Nevertheless, if too much sulphur requires to be removed the cost of conversion goes up, consequently the specifications are held to the limits given.

PHOSPHORUS

The specifications in regard to phosphorus for basic open-hearth iron are very broad. Iron with bessemer phosphorus is sometimes used, and on the other hand, iron with phosphorus to 1.85 per cent is successfully converted into good steel. In this country many of the irons made in the South contain from 0.85 to 1 per cent phosphorus. These are successfully used in the basic open-hearth furnaces, but they are not regarded so favorably by steel makers as irons containing 0.3 to 0.4 per cent phosphorus or lower, since when the phosphorus rises above these limits the heats are apt to require longer for complete dephosphorization; this runs up the cost of conversion and so is very objectionable to the steel maker. Where the phosphorous rises much above one-half per cent, phosphoric acid becomes an element of appreciable importance in the open-hearth slag, and this being in the form of phosphate of lime may be made to give the slag a commercial value so that what was a liability may become an asset, but this subject can be better treated in connection with the duplex process.

MANGANESE

The manganese specifications for basic open-hearth iron are about as broad as the phosphorus specifications, iron being used from that only having a trace of manganese up to that having one and one-half per cent or more. Formerly but little attention was paid to this, but in recent years steel makers have come increasingly to believe in the protective action of the manganese in preventing the over-oxidation of the iron, and the tendency is consequently to specify manganese 0.15 per cent or higher.

Iron Used in Compound Processes for Steel Making

In a conversion of iron into steel, the bessemer process has the advantage of large tonnage per unit of steel-making capacity, and, therefore its plant cost is very low. The open-hearth process, on the other hand, has the advantage of better quality of material produced and of considerably smaller conversion losses because the oxygen for oxidizing the metalloids of the iron is supplied to a very considerable extent by iron ore charged into the furnace, and the iron of this ore passes into the bath and increases the yield. This is particularly true in regard to the removal of phosphorus, since the loss involved in doing this in the basic bessemer conversion is very high, 15. to 18. per cent.

In order to obtain the advantage of both processes, attempts have been made at various times during the last forty years to use one type of furnace for one portion of the operation and the other type for the remainder, transferring the metal from one furnace to the other. These combined processes known as duplexing or triplexing, according to the number of furnaces used, were never very successful until the de-

velopment of the enormous ladle handling cranes of the present day made the transfer a matter of a few minutes, and effected it in such large masses of metal that the heat losses were insignificant. This development has occurred only within the last few years so that the evolution of the compound processes for steelmaking is by no means complete.

The iron for these processes has the least rigid specifications of any. Phosphorus may be present in any amount, and quite high sulphur can be eliminated without much expense. The silicon is eliminated in an acid-lined bessemer converter, so does no harm unless present in excessive amounts, when it merely increases the time required for blowing. This adaptability to a wide range of irons is one of the causes that has brought about the introduction of the duplex process so rapidly in the last few years.

SILICON

The silicon for this process is generally desired about the same as that in the bessemer process, because not only is the silicon eliminated in the bessemer converter, but the carbon is commonly blown down to between 0.15 and 1 per cent, so that the iron is converted into steel, except for the phosphorus, which is still in the material and remains to be eliminated. The silicon is wanted about the same as in the bessemer, so as to yield the heat to keep the metal molten at the high temperature corresponding to the removal of the carbon, about 1.20 to 1.50 per cent. This is the easiest and cheapest iron there is to make from the furnaceman's point of view, and this adds to the commercial desirability of the duplex process.

PHOSPHORUS, MANGANESE AND SULPHUR

Specifications for these are virtually the same as for basic open-hearth iron, and the same general considerations hold in regard to them. There enters at this point, however, the condition mentioned earlier concerning phosphorus.

The duplex process enables the slag resulting from oxidation of the silica to be separated entirely from that arising from the oxidation of the phosphorus. As a result the phosphoric acid in the slag can be raised to a very much higher percentage with this process than with the straight open-hearth process.

When a considerable percentage of phosphorus is present, the process may be so manipulated as to raise the phosphoric acid to a point where the slag becomes a commercial asset valuable in proportion to its content of this substance, and under these conditions it may well be that high phosphorus is more desirable than low, because it permits the production of a higher grade or a greater quantity of slag, valuable as fertilizer. I have no knowledge of cases in which the phosphorus has been deliberately raised on this account, but a condition in which this would be might easily arise, iron containing less than 1 per cent of phosphorus can be so handled for conversion into steel that a commercial fertilizer of very important value is recovered.

Iron for Puddling

This variety of iron was formerly of great importance, as puddling represented the sole means of converting cast iron into a forgeable product: wrought iron, and all the standard products now made of steel, such as rails, plates, structural material, wire, etc., were at that time made of puddled iron. This process has, however, in recent years declined to an insignificant fraction of its former greatness, due to the greater cheapness with which steel can be produced and the superiority of that material for most purposes.

In spite, however, of the predictions to the contrary, wrought iron has not died out altogether, but has, on the contrary, in recent years rather arisen in public esteem for certain purposes. Its weldability is admittedly greater than that of steel, and for most forging purposes it is much preferred to steel on that account. Certain rolled products, moreover, are preferred by some consumers when made of wrought iron rather than steel. This is notably true in regards to materials which are required to resist rust, especially sheets for roofing and siding purposes and welded pipe. The makers of these products in steel have waged a vigorous warfare against the conviction that wrought iron was better, but these products continue to be made of wrought iron and sold at a price considerably higher than that of the steel products.

The specifications for "forge" iron are rather broad and not very definite.

SILICON

Iron puddles more easily when the silicon is low, but some of the best grades of puddled iron have always been made of comparatively high-silicon iron, No. 2 foundry. The "gray forge" iron, which was the established grade for puddling purposes in the old days, ran from about 0.75 to 1.25 per cent silicon.

SULPHUR

The sulphur specifications for this iron are not at all strict. Sulphur exercises a less objectionable influence on wrought iron than on steel, and it is probable that the sulphur in the gray forge of the old days ran ordinarily between 0.04 and 0.08 per cent.

PHOSPHORUS

This iron is notable from the fact that it is desired to contain a certain amount of phosphorus, about 0.3 to 0.4 per cent, and where it is made at the present time, open-hearth slag or some similar material containing phosphorus is charged if necessary to raise the phosphorus up to this point. Most of the phosphorus disappears in the puddling process, though good puddled iron may contain as much as 0.2 per cent of this element.

MANGANESE

There are no particularly definite specifications for manganese in this iron, but it is understood that the best results are produced when there is a moderate amount of this element present, between 0.5 and 1 per cent.

CARBON

With this iron, as with the steel-making irons, no attention is paid to the carbon.

Ferro-alloys

Various alloys of iron with other elements are made in the blast furnace. Formerly it was the only means for doing this, but the developments of recent years have shown that certain alloys can be produced to better advantage in the electric furnace, and that some others can be produced therein which the blast furnace cannot produce at all. This has to a certain extent narrowed the field of the blast furnace in regard to ferro-alloys.

MANGANESE ALLOYS

There are two of these, spiegeleisen and ferromanganese varying from each other only in their percentage of manganese. The former was the earliest developed and was largely used in the days of the bessemer process, especially in rail manufacture; it has been very largely superseded in recent years by ferromanganese.

Spiegeleisen takes its name from the fact that the

manganese carbide forms in large flat flakes, half as large as one's thumb nail, which shine like mirrors in the face of the broken pig. Spiegeleisen contains from 15 per cent to 30 per cent of manganese, depending principally upon the amount of the element present in the ore from which it is made.

The amount of carbon in this alloy varies from 4½ to 5½ per cent.

No attention is in general paid to the silicon in this material, although in some cases a special product, high in silicon—6 or 8 per cent—as well as in manganese, is produced. This is known as silico-spiegel.

Both these products should have as little phosphorus as possible. The bessemer limit is usually specified for them, but they may be used containing higher percentages if it suits the conditions of the steel maker in other respects; that is, if the phosphorus in his raw steel is low enough to stand the additional quantity brought in by the spiegel, and the price at which he can buy it is low enough.

Ferromanganese.—The standard alloy of this name contains 80 per cent manganese, about 5 to 6½ per cent carbon. No attention is paid to the quantity of silicon. Phosphorus is permitted up to about 0.2 per cent in ordinary practice, the larger quantity being allowed on account of the fact that the weight of the ferrosilicon used is much smaller than that of spiegel, owing to the difference in the manganese contained.

Ferromanganese is often made containing smaller percentages of manganese than that given. The alloys still go by the name of ferromanganese when the latter element is as low as 40 to 50 per cent, but this is not as desirable, since this allow is introduced in the solid condition sometimes preheated into the molten steel running from the converter or open-hearth furnace into the ladle. It is desirable that the amount of metal so introduced shall be as small as possible, so as to produce its chilling action on the bath and increase the certainty of its uniform distribution through the metal, and obviously the higher percentage of manganese in the ferro the smaller weight required.

These are very largely the same considerations which have brought about a substitution of ferro for spiegel. When the latter is used, the quantity required is so great that it cannot be introduced solid, but must be melted in a separate cupola and run into the ladle as a liquid. This is more trouble and is out of the question when low-carbon steel is to be made, because the quantity of carbon in proportion to the manganese is three or four times as high in spiegel as it is in ferro, and in order to introduce enough manganese into the steel with the former, more carbon would be simultaneously introduced than could be tolerated for some purposes.

FERROSILICON

There are two varieties of this material, blast-furnace and electric-furnace. In the latter, there are very high percentages of silicon—from 50 to 80 per cent, but these products cannot be made in the blast furnace. Blast-furnace ferrosilicon is practically never made with any more than 15 per cent silicon. The silicon in the ordinary grades varies from 8 to 14 per cent.

This alloy is notable for the fact that carbon is kept out of the iron by the rise of the silicon, as previously described. This action begins with about 4 per cent silicon. When this point is reached the carbon decreases to the point where the graphite flakes, instead of appearing continuous in the fracture of the iron, are separated by areas of white, and this action continues as the silicon rises.

The reduction of carbon and increase of silicon gives the iron a sort of greasy look, and irons containing from 4 to 8 per cent silicon are called silvery irons, because their color is much lighter than that of normal irons. These irons are to some extent regularly made for foundry purposes, foundrymen using them to raise the silicon in a mixture otherwise too low. For such uses, of course, the phosphorus specifications are unimportant, but most of this is used in certain methods of steel manufacture, and therefore requires to be below the bessemer limit in phosphorus.

No particular attention is paid to the manganese in this metal.

FERROCHROME

Ferrochrome was formerly made in the blast furnace, but never as far, as I am advised, in America. I am informed on good authority that the maximum amount of chrome that could be introduced into the iron was 30 per cent, no heat obtainable being sufficient to raise it higher than this. The introduction of the electric furnace has brought about the production of alloys much higher in chrome and correspondingly more desirable, so that the blast furnace no longer competes in this field.

Statistics of Chilean Nitrate Industry

The nitrate of soda manufactured in Chile during the month of June, 1916, amounted to 5,153,701 Spanish quintals of 101.4 pounds, against a production of about 5,353,900 quintals in May of this year, 2,613,976 quintals in June, 1915, 5,752,929 quintals in June, 1914, and 5,101,301 quintals in June, 1913, according to *Commerce Reports*. Exports totaled 4,217,810 quintals, against 5,143,500 quintals in the preceding month, and shipments of 3,866,168 quintals in June, 1915, 4,053,186 quintals in June, 1914, and 3,649,624 in June, 1913.

These figures show that production and exportation are still on a large scale though not at maximum. At present exportations are materially influenced by the amount of ocean tonnage available.

For the twelvemonth ending June 30, 1916, both production and exports were 70 per cent greater than in the preceding year, but fell somewhat short of the totals for 1913-14 and 1912-13, as the following summary discloses:

	1911-12	1912-13	1913-14	1914-15	1915-16
	Quintals	Quintals	Quintals	Quintals	Quintals
Production	54,572,965	59,450,462	62,322,617	34,091,243	57,715,614
Exportation	54,254,471	58,492,375	58,751,291	32,070,714	55,285,814
To Europe and Egypt	41,407,349	43,051,680	44,534,131	16,939,650	29,017,777
To United States	10,983,701	13,392,999	12,290,782	13,437,418	23,484,842
East coast	9,896,768	12,336,221	11,222,657	12,295,221	20,390,839
West coast	1,086,933	1,056,778	1,068,125	1,142,197	3,094,003

Prices in Chile have shown rather slight changes recently. For ordinary nitrate, or 95 per cent, the price has been around $1.77 per quintal for immediate deliveries with prices $0.02 to $0.04 higher for later deliveries. The difference between quotations for refined and ordinary grades has increased and is greater than has been ruling during the past year. For 96 per cent grade of nitrate the quotation has been about $1.90 per quintal for delivery during early future months. During the first part of July the market became less firm, and present prices are slightly lower than those just mentioned, though very few sales by manufacturers are announced.

Platinum in U. S. in 1915.—According to a U. S. Geological Survey report, crude platinum was produced in California and Oregon in 1915 to the extent of 741.91 oz. Platinum from refiners of platinum, gold, and copper, was 8665 oz. of which 1587 oz. was domestic.

Features of the New Copper Smelting Plants in Arizona*

BY A. G. MCGREGOR

During the past five years five new copper-smelting plants have been built and put into operation in the State of Arizona. The monthly copper output from these plants averages from 5,000,000 to 18,000,000 lb. Previously, there never was as much activity in the copper-smelting plant construction in the same length of time in all the rest of the world.

Naturally, in this amount of work, some new problems were met and new features in plant design and equipment developed. Some of these features are described in this paper.

Concentrate Hauling, Unloading and Sampling System

CONCENTRATE CAR

The International Smelting Company has provided at its plant at Miami specially designed cars for hauling the concentrates from the mills of the Inspiration Copper Company and the Miami Copper Company. The car has a bottom that is readily made tight to hold flotation concentrates and is quickly and cheaply unloaded. Figs. 1, 2 and 3 show views and details of the car.

The main feature of this car is the slot in the bottom throughout its length, which is closed by means of short planks that overlap like shiplap as shown by Fig. 1. At one end of the car an iron gate operated by a screw and hand wheel is provided, which clamps or presses the planks together, making the bottom tight. A removable tapered plug rests vertically over this gate when the loading of the concentrates at the mill commences.

*A paper to be presented at the Arizona Meeting of the American Institute of Mining Engineers in September, 1916.

A concentrate unloading pocket (Fig. 4) 180 ft. long is provided at the smelting plant, which has a conveyor belt running throughout its length underneath the track. To unload a car the vertical plug at the end of the car is lifted by means of a chain hoist which is supported by a trolley overhead. The gate at the end of the car is opened approximately 18 in. The removal of the plug leaves a hole down through the concentrates. The concentrates are poked through the hole from the top of the car until it is convenient for a man to stand on the bottom of the car and draw one of the slats in the bottom toward the gate end of the car. The concentrates are then raked down with hoes on their natural angle of repose, which is nearly vertical, until the next slat is partly uncovered, when it is pulled toward the gate end of the car. This operation progresses until the opposite end of the car is reached. The slats and the grooves supporting them are then carefully swept off and cleaned with a broom; the gate is screwed back, pressing the slats together, and the plug is lowered into place. The car is then ready to be taken back to the concentrator for another load.

CONCENTRATE SAMPLER

Fig. 5 shows diagrammatically the scheme used for sampling the concentrates. It will be noted that the conveyor from the unloading pocket discharges onto a shuttle conveyor (a tripper on the former conveyor could have been substituted for the shuttle conveyor, but it would not have handled the sticky concentrates as well). Buckets attached at their ends to chain belts are arranged to cut through the stream of concentrates as they are discharged onto the shuttle conveyor. The chains are driven and supported by sprocket wheels. The arrangement is such that at the highest point in their travel the buckets are in an inverted position. At this point they pass under a revolving shaft which has

FIG. 1—6-TON CONCENTRATE CAR. FIG. 2—SECTION *A-A* OF FIG. 1. FIG. 3—GATE-OPERATING MECHANISM OF CONCENTRATE CAR

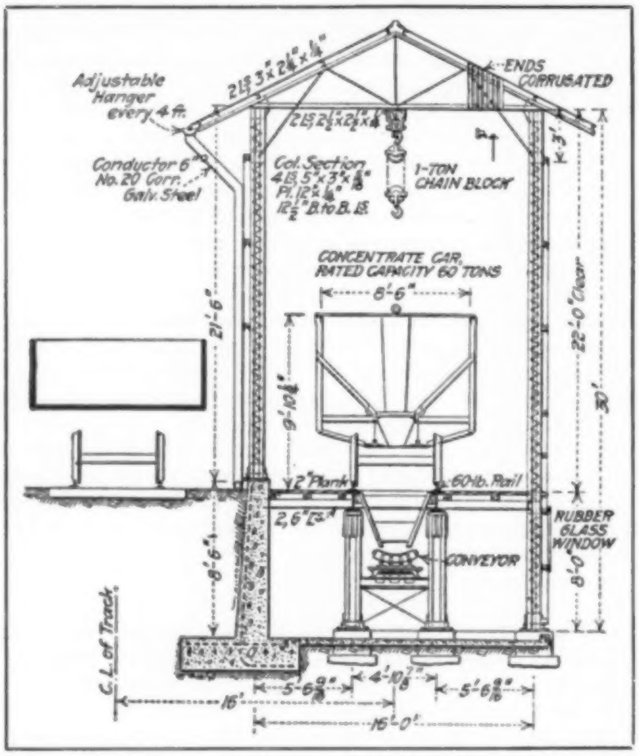


FIG. 4—SECTION THROUGH CONCENTRATE UNLOADING POCKET

a number of knockers, made of 6-in. belting, attached to it. These knockers slap the bottom of the buckets, jarring loose any concentrates tending to stick to them. This arrangement works satisfactorily on ordinary table and vanner concentrates, but is not satisfactory with flotation concentrates on account of the varying load on the conveyor belt, the flotation concentrates being unloaded from the car in large shunks.

BEDDING BINS

Fig. 6 shows a cross-section of the bedding bins used in connection with the concentrate car and sampler just described. The bins are 150 ft. long and have a total capacity of 9000 tons of charge. The concentrates are delivered by belts from the car-unloading pocket to any one of the three conveyors passing over the bins. Each belt has a motor-operated tripper, which travels back and forth throughout the length of the bin. Each tripper is arranged with two cross-belts, which discharge material on both sides of the tripper, instead of the ordinary chutes that would clog with the sticky concentrates. These cross-belts also permit of a wider top on the ore bed than could be obtained with ordinary chutes. The cross-belts of the tripper as well as the long belts running over the bins and all the other belts handling sticky concentrates are speeded to 400 ft. per minute, which aids in discharging the sticky material from the belt when it passes over the pulley at its head end or the pulley of the tripper. An oscillating deflector is so arranged that the material passing over the tripper is discharged, first, on one of the short cross-belts and then on the other. This is done to provide an even distribution of the material over the top of the beds, making the height of the bed on both sides of the tripper the same. The tripper is reversed at each end of its travel by the reversal of its propelling motor through a magnet-switch control. The bins have "V" bottoms with a slot 2 ft. 4 in. wide running throughout their length. This slot is covered with short planks which are readily removed, and as the reclaiming progresses, they are merely moved back in the slot. The concentrates are raked down with hoes and allowed to discharge, through the opening in the bottom thus provided, onto the conveyor belts underneath. The concentrates are bedded in these bins with a proper amount of limestone and pyrite and the available secondaries, each bin comprising a bed. Storage bins for storing finely crushed lime rock, secondaries, pyrite, etc., are provided and arranged so that the fine material from these bins is delivered by a conveyor and discharged just ahead of the concentrates onto the belts leading up over the bedding bins. The material next to the bedding belts, therefore, consists largely of finely crushed lime rock, which is a further aid in the discharge of the sticky concentrates from these belts.

Roaster or Dryer Plant

Figs. 7 and 8 show end and side elevations respectively of the International Smelting Company's roaster or dryer plant. The main features of this plant consist in the method used for conserving the heat and in the placing of the Cottrell fume treaters directly above the furnaces. The roaster furnaces in this plant are used for drying the concentrates and are not used for roasting, as the charge contains no excess sulphur; in fact, it has been necessary to have some pyrite shipped in from Bisbee in order to raise the sulphur content of the charge sufficiently to prevent the production of mattes too high in copper for good clean slags.

CONSERVATION OF HEAT IN FURNACE

The furnaces are air-cooled. The cooling air, after passing through the furnace arms, is conducted up the central shaft to the top, thence down to the oil fireboxes connecting with the two lower hearths of the furnace. This gives preheated air for the combustion of the oil and conserves the heat absorbed by the cooling air. To further conserve the heat of the furnace, the linings are 12 in. thick. The outer 4 in. of lining, between hearths, is made of "Nonpareil" insulating brick. The manufacturers of these brick claim that 4 in. of their brick is equivalent in heat insulating value to 40 in. of ordinary brick. The tops of the calcine hoppers of these furnaces are insulated from the lower floor of the furnace building, just above them, by an air space. The calcine hoppers have non-conducting lining consisting of 2½ in. of Nonpareil insulating brick and a 1-in.

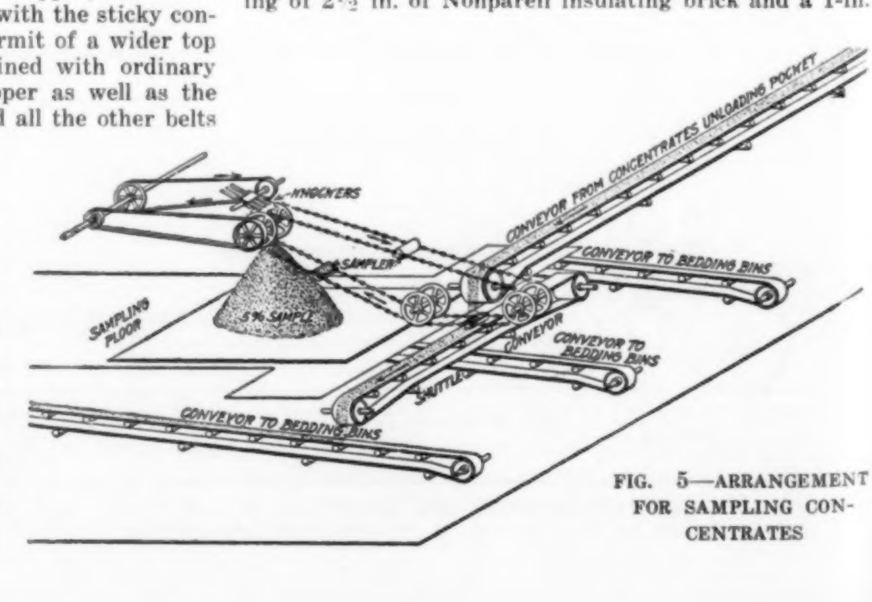


FIG. 5—ARRANGEMENT FOR SAMPLING CONCENTRATES

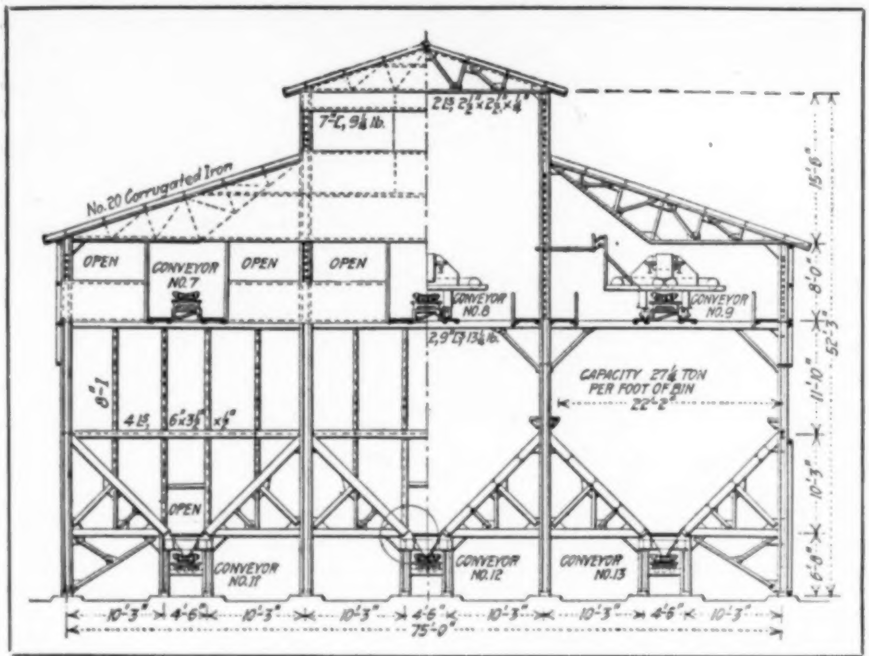


FIG. 6—CROSS-SECTION OF BEDDING BINS

layer of reinforced concrete. The reinforced concrete is to take the wear and erosion caused by the heated material inside the hopper, as the Nonpareil brick will not stand much wear or rough usage.

COTTRELL DUST-COLLECTING SYSTEM FOR ROASTER AND DRYER FURNACES

The Cottrell equipment for treating the gases from this plant consists of twelve units of twenty tubes each. The tubes are of lap-welded steel 13 in. in outside diameter and 15 ft. in length. They are flanged outward, or "Vanstoned" at each end, which reduces the brush discharge caused by sharp corners and makes a good means of connection to the upper and lower diaphragms. Suitable lugs are welded to the pipes against which the hammers strike when vibrating the tubes to shake off the collected dust. The electrical equipment for this installation is so arranged that the voltage used may be varied from 50,000 to 100,000 volts. The treater tubes were planned for a velocity of 5 ft. per second for the gases passing up through them.

The recovery of dust by this Cottrell treater system is practically perfect.

The main feature of this installation is in its arrangement, which permits the gases to pass directly up from the furnaces through the header flue, the tubes and the stacks, the gases rising continuously from the furnace hearths to the outlet of the stacks.

Blast Furnace

Fig. 9 shows a general end elevation of the blast furnaces at the Calumet & Arizona Mining Company's plant at Douglas. These furnaces are 40 ft. long by 4 ft. wide at the tuyères. The ores and materials smelted in these furnaces are bedded so that the charge coming to the charge bins over the furnaces is thoroughly mixed. A coke bin and ore bin are provided on both sides of each

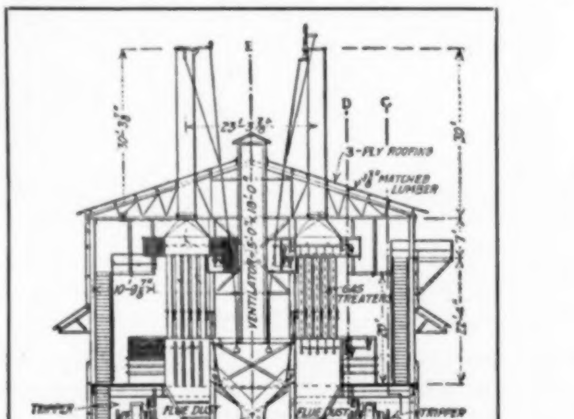


FIG. 7—END ELEVATION OF ROASTER AND DRYER PLANT, INTERNATIONAL SMELTING CO.

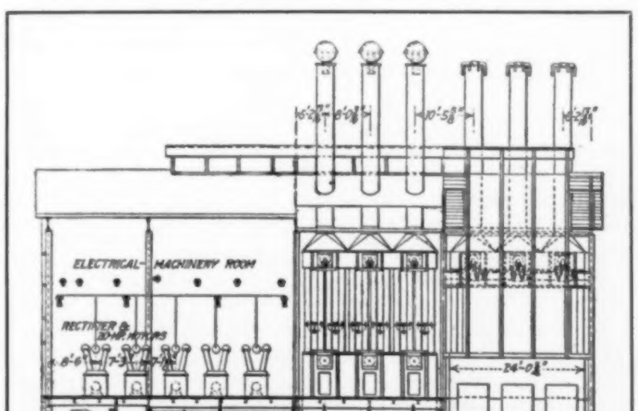


FIG. 8—SIDE ELEVATION OF ROADSTER AND DRYER PLANT, INTERNATIONAL SMELTING CO.

furnace. Each furnace has four charge cars, two on each side. The cars are 20 ft. long. When receiving a charge of ore or coke, the cars are resting on track scales. Each car has four compartments and the bins overhead have a gate corresponding to each compartment, so that the amount of charge for any part of the furnace can be regulated to suit the conditions. The car is propelled from the bins to the charging position at the furnace, a distance of 7 ft. or 15 ft. (according to whether a charge of coke or a charge of ore is being moved) by means of an electric motor geared to two wheels of the car. Fig. 10 shows a view of the charge car under the charge bins.

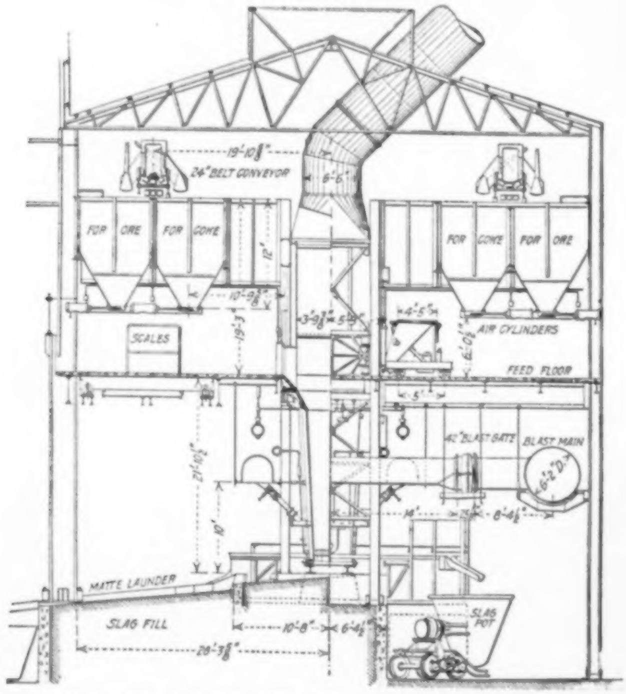


FIG. 9—SIDE ELEVATION OF BLAST-FURNACE PLANT, CALUMET & ARIZONA MINING CO., DOUGLAS

The furnace side jackets are in one length, 16 ft. 6 in. long and are 40 in. wide. It will be noted that the bustle pipe is combined with the truss or girder, which takes the outward thrust of the jackets at their midpoint. This simplifies the construction and gives more room around the bustle pipe for the water piping, etc.

Fig. 11 is a view showing the tuyères and bustle pipe.

The bridge plates for the furnace bottoms are of structural steel; ½-in. plates are riveted to 6-in. I-beams. The I-beams are spaced 12½ in. apart. The cooling of the bottom is effected entirely by the surrounding air. The I-beams riveted to the plates undoubtedly increase the effectiveness of the cooling. The I-beams supporting the bottom are also used for holding the outward thrust of the bottom ends of the jackets. This thrust

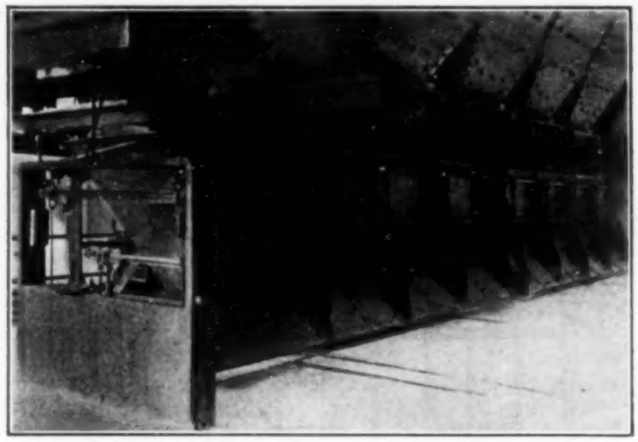


FIG. 10—VIEW SHOWING CHARGE CAR UNDER BINS

is carried into the beams by means of steel rods threaded at one end and flattened at the other. The flattened ends are riveted to the webs of the beams and a nut on the threaded end holds a lug against the bottom end of the jacket.

It will be noted that the furnace tops and charge doors are of structural steel in the form of air jackets. An air space is provided between the inner and outer sheets of the furnace tops. The lower end of this air space connects with the outside air while the upper end

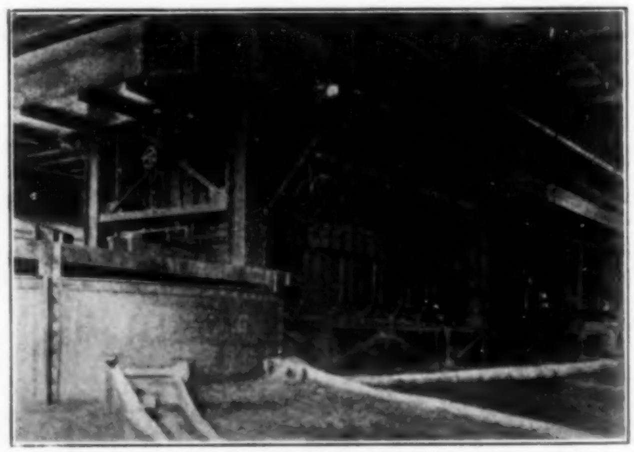


FIG. 11—VIEW SHOWING TUYERES AND BUSTLE PIPE, BLAST FURNACE OF CALUMET & ARIZONA MINING CO., DOUGLAS

connects with the inside of the furnace top. The cool air is drawn in at the bottom and discharged at the top into the furnace gases going to the chimney, thus insuring a positive air circulation which keeps the sheets of the air top properly cooled. The furnace charge doors are jacketed in a similar manner.

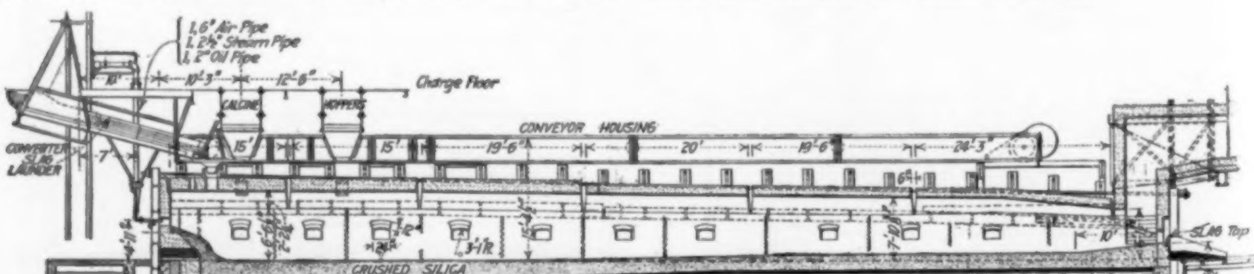


FIG. 12—SIDE ELEVATION OF REVERBERATORY FURNACE, INTERNATIONAL SMELTING CO.

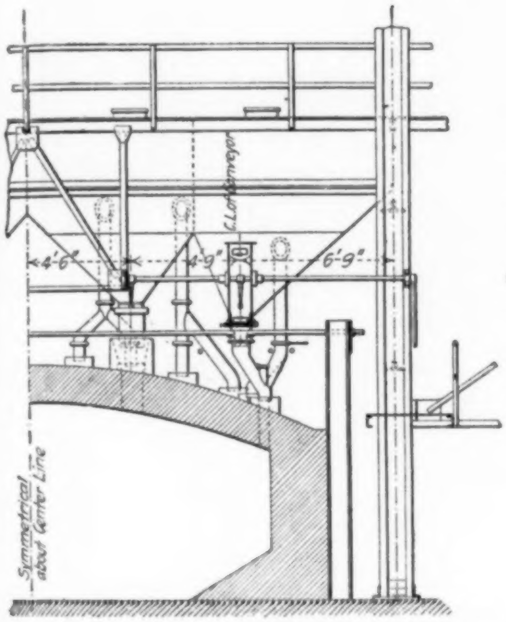


FIG. 13—SECTION REVERBERATORY FURNACE SHOWING CHARGING ARRANGEMENT

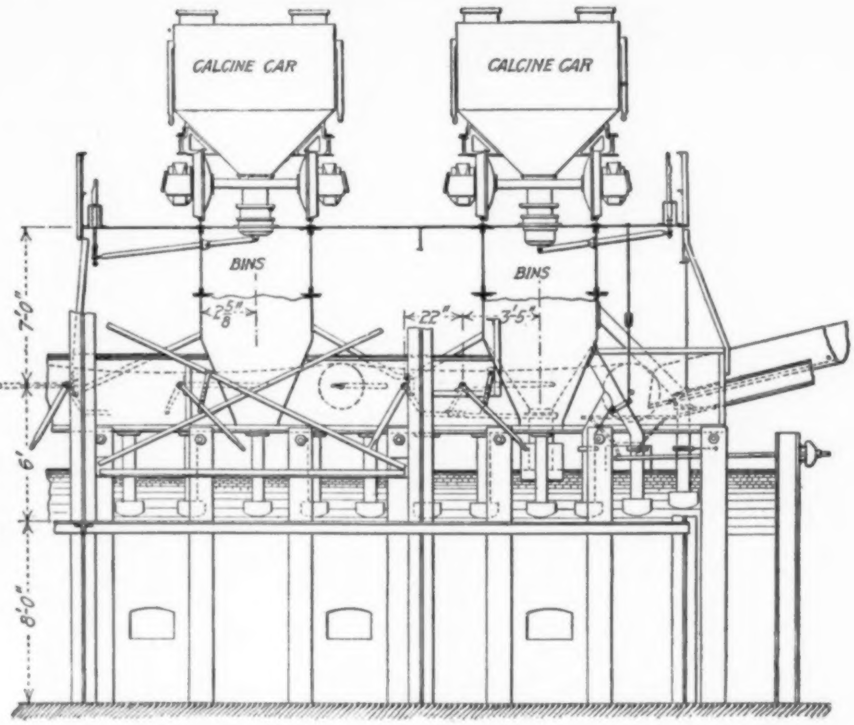


FIG. 14—LONGITUDINAL SECTION REVERBERATORY FURNACE SHOWING CHARGING ARRANGEMENT

These furnaces have been in use for three years, smelting as high as 1400 tons of charge each per day, and no repairs or replacements have been made in furnace water jackets and no warping has taken place in the air-cooled tops.

Reverberatory Furnaces

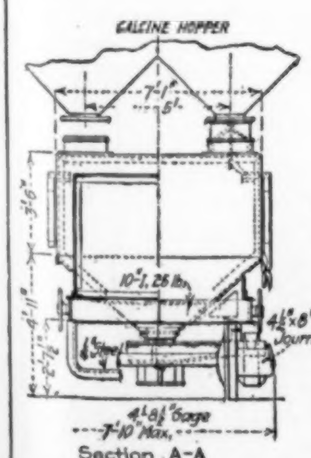
Fig. 12 shows a side elevation of a typical reverberatory furnace at the International Smelting Company's plant which has several features worthy of mention.

FURNACE BOTTOMS

It was especially desirable at this plant, on account of difficulties at another plant, to avoid any trouble with furnace bottoms in starting up. To accomplish this, broken slag was brought in railroad cars from the Old Dominion smelter and was melted in a small blast furnace, obtained by setting up a number of discarded furnace jackets and a motor-driven blower, on the site for the reverberatory furnaces. The molten slag thus obtained was conducted in launders to the foundations of the reverberatory furnaces. Heavy concrete beams and struts were provided between the furnaces for taking the thrust from the lower ends of the buck stays. Later, the spaces between the concrete struts and the beams were filled in with molten slag obtained from the regular operation of the reverberatory furnaces. The slag bottom was covered first with a 4-in. layer of fireclay and then a 27-in. layer of silica (94 per cent SiO_2) crushed to minus ¼ in. These bottoms gave no trouble whatever in starting up.

FURNACE FETTLING AND CHARGING SYSTEM

The method of charging, instead of fettling only, along the side walls of reverberatory furnaces, now so successfully used by the Canadian Copper Company and the Anaconda Copper Mining Company, was developed after the construction of this plant was well along. The plant was laid out for charge tracks running at right angles to the furnaces near the firing end. In order to distribute the charge along the sides of the furnaces, charge hoppers were located under the charge



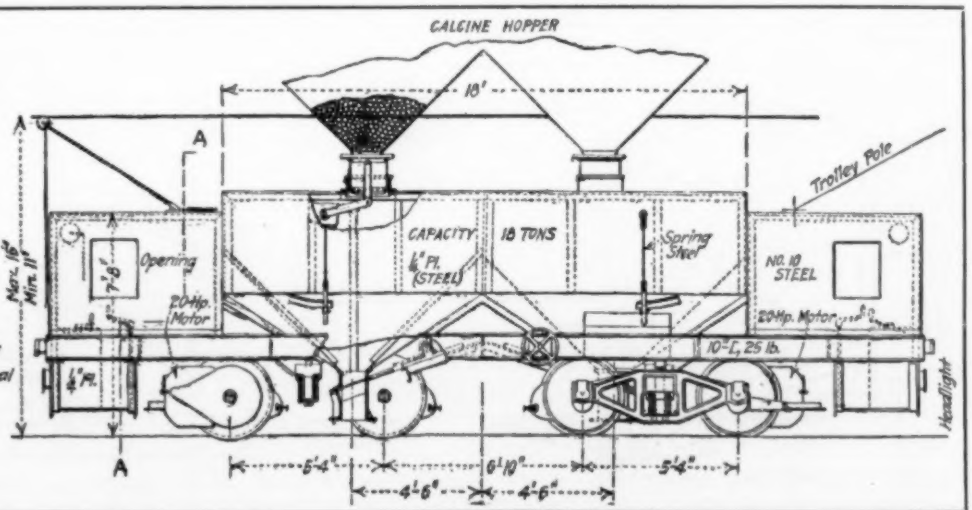


FIG. 15—END ELEVATION OF CALCINE CAR. FIG. 16—SIDE ELEVATION OF CALCINE CAR

tracks directly over the side walls of the furnaces. Drag-chain conveyors were installed, one over each side of each furnace, which received the charge from the charge hoppers (see Figs. 13 and 14). Under these conveyors, approximately every 30 in., suitable down-spouts with gates are provided so that the charge may be distributed along the side walls of the furnaces throughout their length. The bridge wall and side walls at the firing end of the furnaces are charged by drawing directly from the hoppers through suitable spouts.

The floor over the charge tracks around the skimming end of the furnace is paved with firebrick.

CALCINE CARS

Figs. 15 and 16 show end and side elevations respectively of the calcine car used at the International Smelting Company's plant. The feature of this car is the arrangement used for reducing dust losses in receiving and discharging a charge. The car is equipped with four sliding sleeves in the top which are spaced to register with the discharge openings of the calcine hoppers at the roaster plant. When the car is spotted under the roaster hoppers in its proper position, the sleeves are forced up against the calcine hoppers by means of levers on the side of the car. The operating lever is of flat spring steel so that the sleeve can be firmly pressed in contact with the flange at the bottom of the calcine hopper, and held there by a notch in a quadrant on the side of the car. The spring handle insures a good pressure between the sleeve in the top of the car and the flange of the calcine hopper regardless of the small variations in the distance between the top of the car and the calcine hoppers or any lost motion in the connection of the lever with the sleeve. An air vent is provided in the car made of fine woven wire mesh.

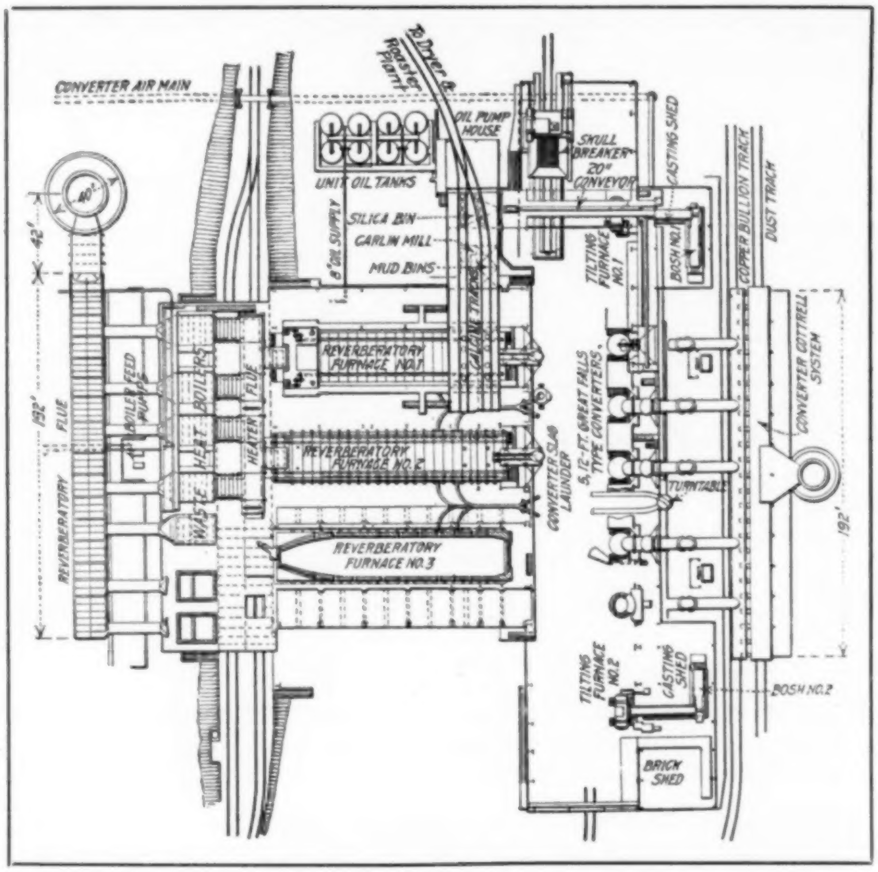


FIG. 18—PLAN OF INTERNATIONAL SMELTING CO.'S PLANT (A) SILICEOUS ORE-CHARGING DEVICE FOR CONVERTER

Fig. 14 shows the sleeves in the top of the reverberatory furnace charge hoppers for receiving the charge from the calcine car. These sleeves are similar to the sleeves in the top of the calcine car. By pressing down on the lever, which is operated from the charge floor, the sleeve is forced up against the flange of the discharge spout of the car. Notches are provided in the lever which engage a catch and thus hold the sleeves in their upper position while the car is being discharged. The pressure of the handle is transmitted to the sleeve, as will be seen from the figure, through a helical spring, so that a good contact between the sleeve and the spout of the car is assured regardless of the lost motion and wear in the operating levers and the variations in the distance between the sleeves in the charge floor and the flange on the discharge spout of the car.

BAFFLING IN WASTE-HEAT BOILERS

By reference to Fig. 17, it will be noted that the header flue between the reverberatory furnaces and the

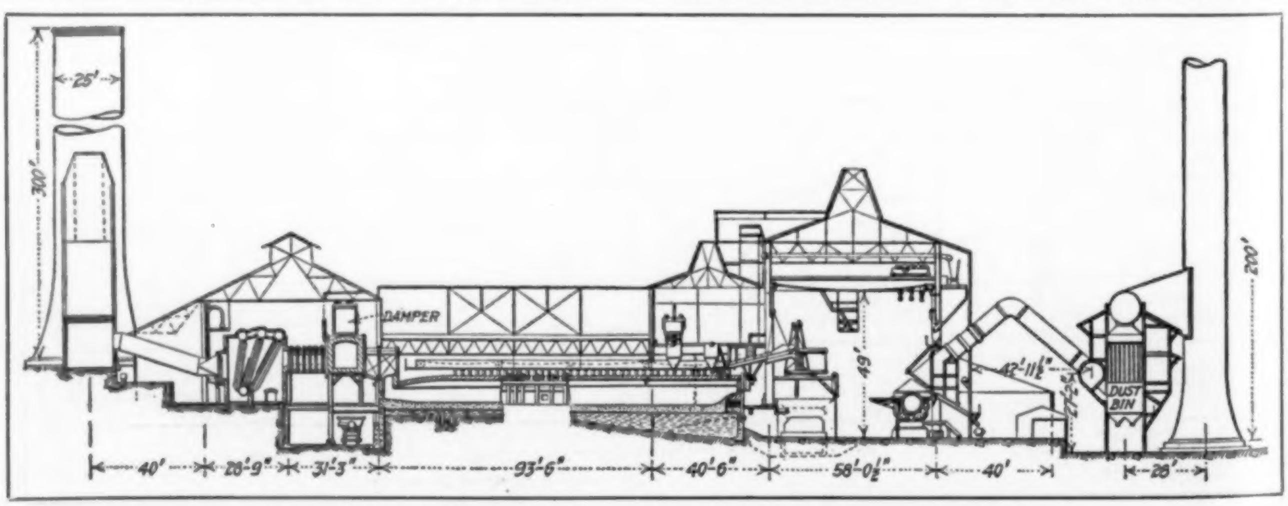


FIG. 17—TYPICAL CROSS-SECTION OF THE INTERNATIONAL SMELTING CO.'S PLANT.

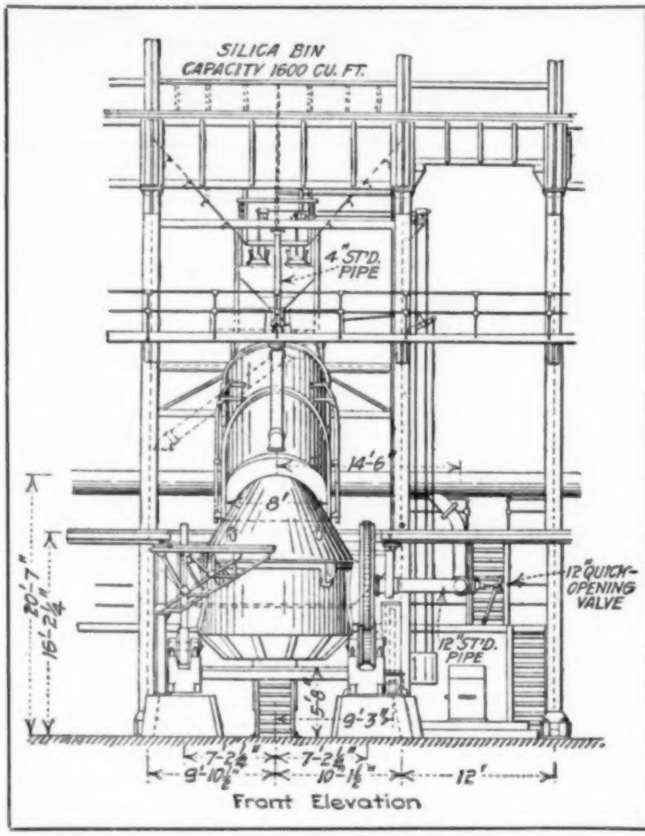


FIG. 19—CONVERTER PLANT, INTERNATIONAL SMELTING CO.

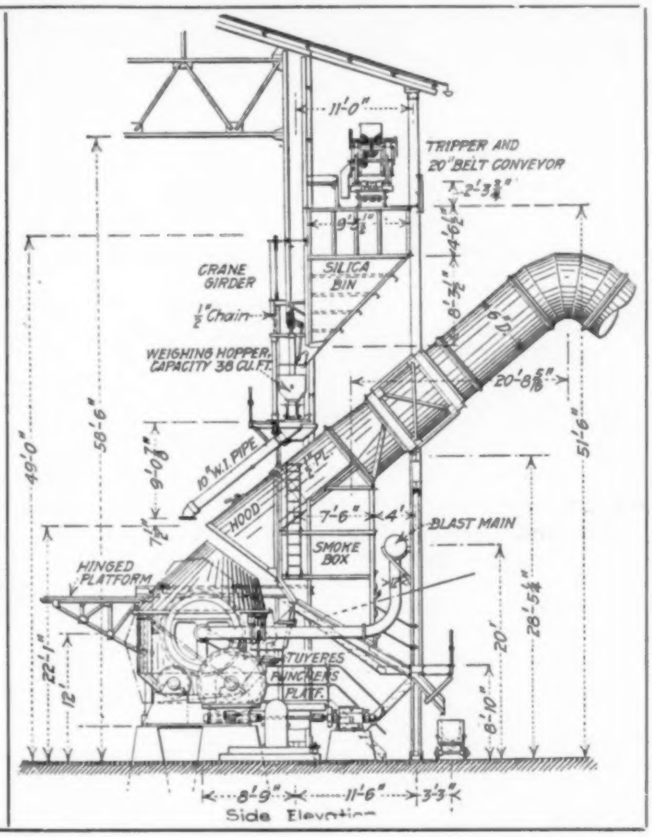


FIG. 20—CONVERTER PLANT, INTERNATIONAL SMELTING CO.

waste-heat boilers, and the connections between the header flue and boilers are well up above the furnace floor level, giving ample head room for the convenience and comfort of the workmen; the bottom of the header flue is 10 ft. 6 in. above the furnace floor level. Also, it will be noted that the boiler-room floor level corresponds to the furnace floor level. This is made possible by reversing the baffling in the Sterling boilers so that the gases enter the front of the boiler near the top and leave the boiler at the rear near the bottom instead of as in the standard setting.

This arrangement of baffling gives equally as good results from the standpoint of water circulation in the boiler, priming, etc., as the standard baffling.

Arrangement of Converter Plants

Southwestern practice is to have the converter plant adjacent to the reverberatory furnaces, arranged so that the reverberatory matte is received through launders, into ladles directly under the converter plant crane. Also they are arranged so that the converter slag may be poured from ladles by the converter crane back into the reverberatory furnaces through launders extending from the converter aisle to openings provided in the roofs of the reverberatory furnaces. The converter slag is usually discharged several feet in front of the bridgewall of the furnace and midway between the side walls. Fig. 17 is a typical cross-section of the International Smelting Company's plant and is typical of the new reverberatory smelting plants in Arizona. Fig. 18 is a plan of the same plant.

Several of the plants are arranged so that the siliceous ore for the converters is drawn directly from bins overhead. Figs. 19 and 20 show a typical arrangement of bin, measuring hopper and chute for accomplishing this operation. This particular arrangement is installed at the International Smelting Company's plant. A weighing or measuring hopper is interposed between the overhead bin and the chute leading to the converter mouth. The hopper is mounted on springs and is connected by levers and links to an indicator readily seen from the operating floor. Any desired amount of charge can be weighed out into the measuring hopper and discharged into the converter, and this can be accomplished entirely through the operation of levers on the main floor of the converter plant.

CONVERTER PLANT CRANES

Most of the newer plants are equipped with 12-ft. Great Falls type converters. These converters weigh,

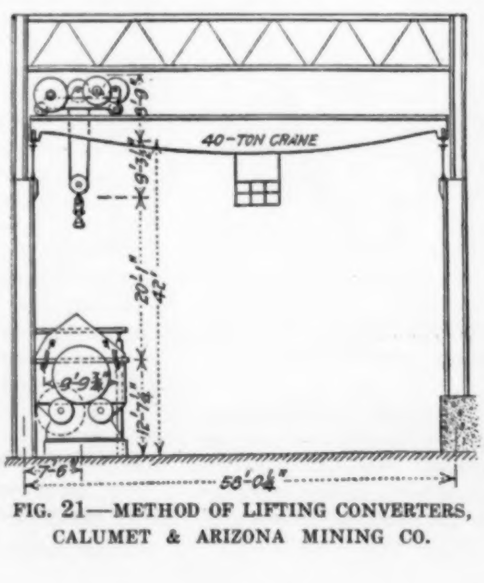


FIG. 21—METHOD OF LIFTING CONVERTERS, CALUMET & ARIZONA MINING CO.

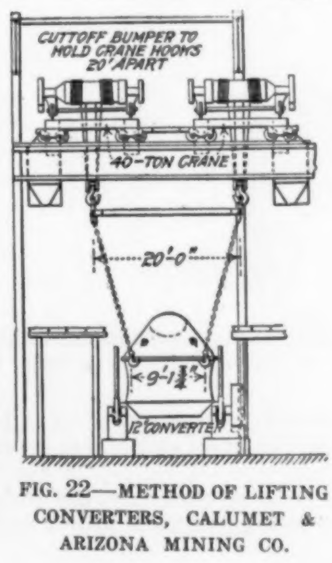


FIG. 22—METHOD OF LIFTING CONVERTERS, CALUMET & ARIZONA MINING CO.

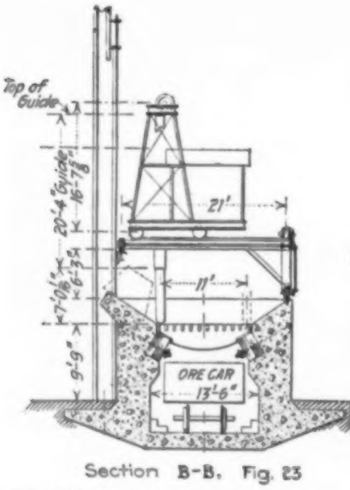


FIG. 23—SKULL BREAKER, INTERNATIONAL SMELTING CO., SECTION B-B

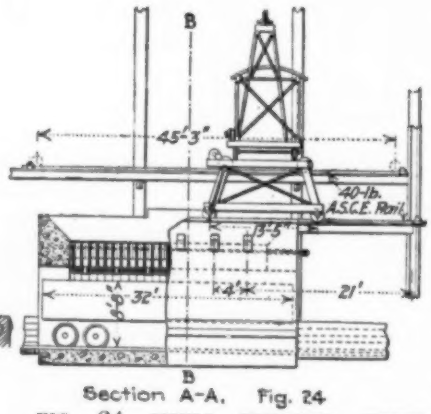


FIG. 24—SKULL BREAKER, INTERNATIONAL SMELTING CO., SECTION A-A

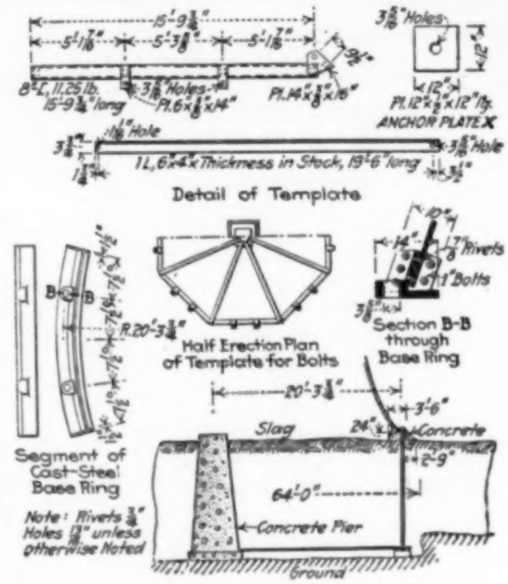


FIG. 27—DETAILS OF SLAG FOUNDATION FOR CHIMNEY OF CALUMET & ARIZONA MINING CO., DOUGLAS

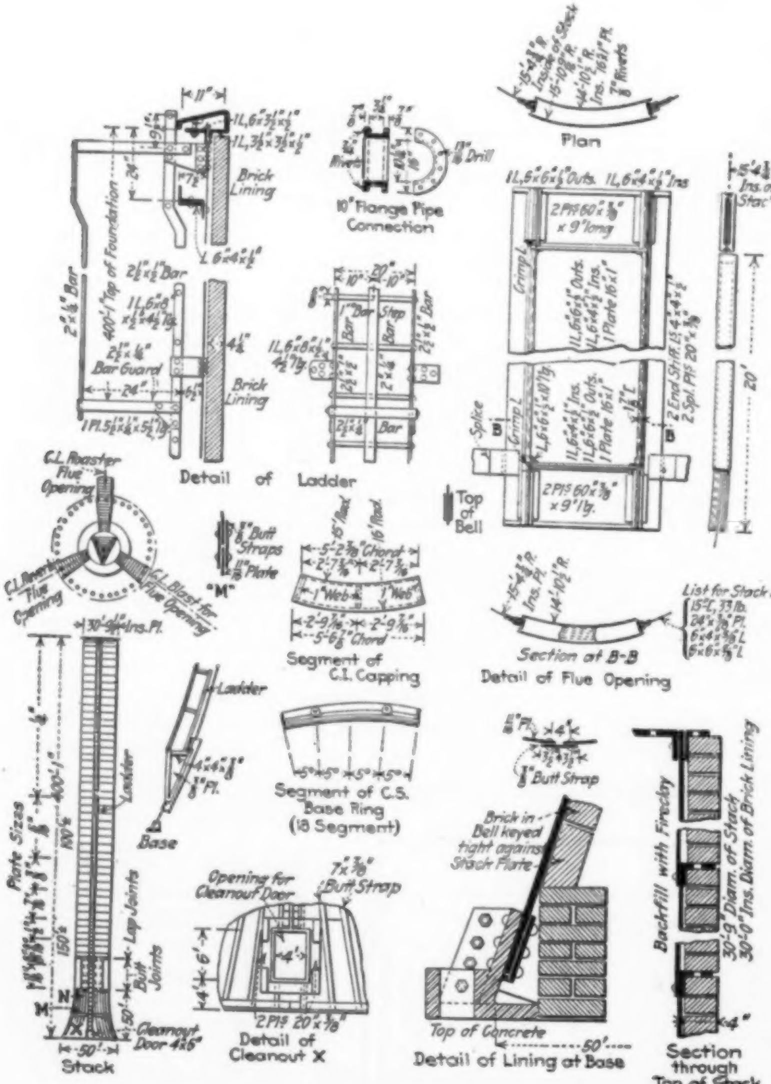


FIG. 26—GENERAL ELEVATION AND DETAILS OF STEEL CHIMNEY, UNITED VERDE COPPER CO.

when lined, approximately 70 tons. Instead of designing the converter cranes for a capacity to lift a converter shell with its lining, as has usually been the practice heretofore, the cranes are designed for a lifting capacity of 40 tons, which is nearer right for the routine work of handling matte, copper and slag in large ladles. Converters with magnesite lining do not have to be moved into and out of their stalls often, but when it is desirable to do this two cranes are used with a lifting rig as shown in Figs. 21 and 22. The converter cranes in all of the Arizona smelting plants are operated by 250-volt direct current. The later cranes are equipped with magnet-switch control.

SKULL BREAKER FOR CONVERTER PLANT

Three of the Arizona converter plants are equipped with skull breakers and a fourth plant is now being thus equipped. Figs. 23, 24 and 25 show the general arrangement of the skull breaker at the International Smelting Company's plant. A hopper about 11 ft. wide by 24 ft. long is provided, the bottom of which consists of cast-steel bars with projecting lugs, so that a grating is obtained for the bottom of the hopper with openings throughout about 9 in. square. A small traveling bridge is provided over this grating, and mounted on this bridge is a trolley which travels transversely to the path of the bridge. In the trolley is mounted a motor-driven hoist which raises a hammer in the form of a long weight that works in a guide. The hammer and guide are mounted on a trolley with the hoist. The hoist operator raises the hammer and allows it to drop on the skull in a manner similar to the operation of the ordinary type of pile-driver hammer. When the skulls are broken into fragments sufficiently small to pass through the grating, they drop into a steel railroad car underneath. The bridge and trolley travel permit the hammer to be spotted over any skull on any part of the grating.

Chimneys

THE LARGEST STEEL CHIMNEY IN THE WORLD

Fig. 26 shows a general elevation with details of the large steel chimney at the plant of the United Verde

Copper Company at Clarkdale, Ariz. It is 30 ft. 9½ in. in diameter inside the steel plates and is 400 ft. 1 in. in height, from the base to the top. It is believed to be the largest steel chimney in existence at this time. It has a brick lining 4 in. thick throughout its height.

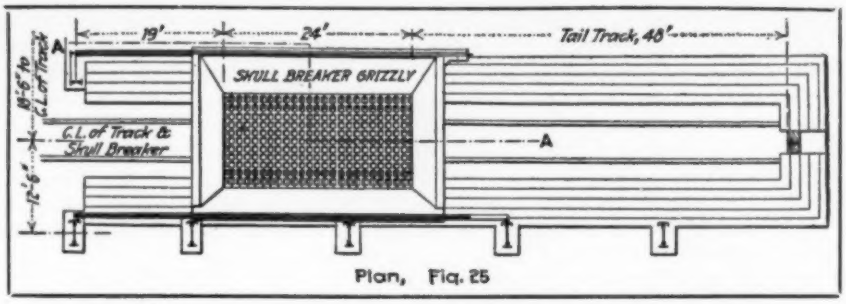


FIG. 25—SKULL BREAKER, INTERNATIONAL SMELTING CO. PLAN

SLAG FOUNDATION FOR STEEL CHIMNEY

Fig. 27 shows the details of the foundation for a steel chimney at the smelting plant of the Calumet & Arizona Mining Company at Douglas. The chimney is 305 ft. high from the top of the foundation and is 25 ft. 9½ in. in diameter inside of the steel shell. It has a hollow-tile lining 4 in. thick throughout its height. The feature of the chimney is in the construction of its foundation. The foundation was cast from molten slag hauled to the site for the chimney in the usual slag pots, instead of concrete or masonry, as is usual for chimneys of this type. A template for holding the anchor bolts was made of structural angles and channels supported on a central concrete pier, and held from turning or moving by a second concrete pier at the outer circumference. The foundation bolts were supported at their lower ends on small concrete piers and they in turn supported the template at other points of its outer circumference not supported by the concrete pier, each bolt having at the top a nut on the under side and one on upper side of the template, forming a secure support. Large washers were provided for the bottom ends of the anchor bolts, over which were laid old steel rails. Blast-furnace slag was then poured over the foundation and adjacent ground, forming the foundation for the chimney. A concrete capping was laid on top of the slag for the cast-steel base-ring of the chimney proper.

Warren, Arizona.

A New Thermo-Electric Method of Studying Allotropic Changes in Iron or Other Metals*

BY PROF. CARL BENEDICKS

In a closed circuit consisting of a homogeneous metal, no electromotive force, capable of causing a current, is produced, howsoever the temperature of any part may be changed, according to Magnus.

If, however, the metal has an allotropic transition point (two-phase point), and some part of the circuit be heated, and remain at a stationary temperature above this point, the circuit can no longer be said to be homogeneous, as the hottest part, according to the assumption, corresponds with a new allotropic state—forming a new phase. However, even in this case, no electromotive force comes into play, as the differences of potential, which *a priori* may be assumed to exist between the two phases, equalize each other at the contact surfaces, on account of the equality of temperature of the contact surfaces.

If, on the contrary, the local heating be not stationary, there is always a possibility that the two contact surfaces may differ in temperature. Let us assume, as a special case, that the locally heated zone might travel with a constant speed along the conductor.

Now, it is known that the temperature of a given transition is always somewhat higher on heating than on cooling, which depends on the fact that a real allotropic transformation takes a definite time to perform in every case.

Thus the contact surfaces between the two phases, as already stated, will have slightly different temperatures, and there is a possibility that a measurable thermo-electric force will come into action.

In fact, it was stated by F. T. Trouton,[1] as early as 1886, that a thermo-electric current is produced when an iron wire is moved through a flame, so that probably a local heating above 900 deg. may occur.

This phenomenon, which, though simple, affords a good lecture experiment,[2] was correctly explained by G. F. FitzGerald as depending on what Sir W. F. Barrett[3] in an interesting note describes as thermo-electric hysteresis.

In the near relation to this effect an observation made shortly before by H. Le Chatelier[4] on silver iodide bears closely on the same point. The substance was enclosed between two metal electrodes, the circuit thus consisting of two different conductors. It was found that at the transition point strong electromotive forces appeared, which primarily were to be ascribed to a thermo-electric action.

It was proposed by Le Chatelier to take advantage of this phenomenon for the study of allotropic transformations. At his suggestion, O. Boudouard[5] made some determinations on nickel steel. Le Chatelier[6] himself published some curves for special steels obtained by this method (platinum wires were fixed at the ends of a short steel specimen, and the electromotive force between them was observed on ordinary heating or cooling).

This method, however, has not been generally accepted, probably on account of a serious inconvenience already pointed out by Le Chatelier. In fact, the electromotive forces which come into play with this arrangement (using an immovable, bimetallic specimen) are occasioned by the inevitable, totally uncontrolled local temperature variations of the furnace, with the consequence that even "the direction of the current observed at the very moment of transition may change with each experiment."[7] Thus, if the temperature degree of a transition point can be determined by this method, every quantitative conclusion as to the intensity of the transformation seems to be excluded.

It might now be asked whether it is not possible to overcome this inconvenience and to find a quantitative method, if, according to the foregoing explanation, a local heating, traveling with uniform speed along a wire, is made use of. It has occurred to the author, first, that this might furnish a quantitative method for ascertaining the existence of allotropic points in the metal (two-phase allotropy); further, that this method might possibly give useful information even in the case of an inner molecular equilibrium, changing with temperature (one-phase allotropy). In fact, the molecular changes

*A paper presented before the (British) Iron and Steel Institute.

[1]Proceedings of the Royal Dublin Society, 1887, vol. v.
[2]The flame, which may possibly cause some chemical alteration, can then be conveniently replaced by a small electric heating device.
[3]Transactions of the Royal Dublin Society, 1900 (2) vol. vii, p. 27; Philosophical Magazine, 1900 (5), vol. xlix, p. 309.
[4]Comptes Rendus, 1886, vol. cii, p. 917.
[5]Revue de Metallurgie, 1904, vol. i, p. 80.
[6]Ibid, p. 134.
[7]Ibid, p. 138.

even in this case probably take some definite time to occur, and the equilibrium, at a given temperature, ought not to be quite identical on heating and on cooling; thus generally a thermo-electromotive force should come into play, even though only single phase is present.

Since, according to the theory advanced by the author,[8] and lately treated in a careful way by K. Honda,[9] such a one-phase allotropy interval exists below the two-phase point A3, it seems to be of special interest to study iron by this method, especially at the temperature interval below A3.

Experimental Arrangement

According to the principles explained above, the experimental arrangement was a very simple one (Fig. 1), as follows:

The metal wire *AA'* to be studied moves through a little electric furnace *B*, the maximum temperature of which is measured by a platinum-rhodium thermocouple, with a compensating arrangement *C* (St. Lindeck and R. Rothe). The free ends of *AA'*, at *F* (a point constant temperature) are connected with the copper wires leading to a mirror galvanometer *G*.

The central part of the wire, *AA'*, is stretched by two strings, running over a horizontal wheel *E* and two

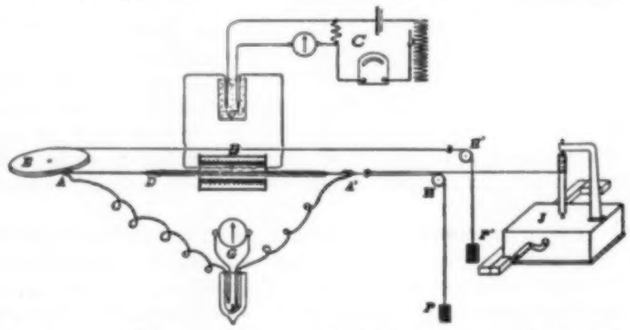


FIG. 1—ARRANGEMENT OF EXPERIMENTAL APPARATUS

small vertical pulleys *H,H'*, and loaded with the weights *P,P'*. A uniform motion is communicated to *AA'* in the one or the other direction by a third string, which is wound on a cylindrical drum by the watchwork *J* (gramophone movement); by suitable guides *I* is easily brought into line with the string at *H* or at *H'*.

The wire *AA'* was sufficiently protected against oxidation by passing it through a fixed silica capillary table *D*.

The furnace being heated to a suitable temperature, the deviations of the galvanometer *G* were read with *AA'* moving first in one and then in the other direction. The half of this difference in millimeters is given as the deviation *U*.

The sensibility of the galvanometer (resistance about 100 ohms) was such that 1 mm. corresponded to 5.6×10^{-8} volts.

The value of the electromotive force resulting must be influenced by several factors, not taking into account the nature of the material itself and the temperature, namely, (1) the speed of displacement, (2) the section of the specimen, and (3) the temperature distribution in the furnace.

1. Smaller variations in the speed of displacement were found to have very little influence, except for the purest iron. A constant speed of 1.6 mm. per second was adopted throughout.

2. The diameter of the wire especially investigated was 1.01 mm. Owing to this thickness a load *P, P'*, amounting to 12.5 grams, could be used, which was enough to secure uniform displacement of the wire.

As will be seen from Series I and II, on the one hand, and III, on the other, the influence of the diameter of the wire is probably very slight.

3. In order to obtain an idea of the temperature distribution of the heated zone through which the wire had to pass, the mean of the observations of the temperature *T* at different distances *X* from the middle of the furnace is given as follows:

Distance X, Millimeters	Temperature T, Degs. Centigrade
+50	300
40	587
30	797
20	848
+10	857
0	858
−10	859
20	837
30	710
40	410
−50	255

This distribution is graphically shown in Fig. 2.

Material Used

The iron selected for investigation was obtained in April, 1912, from the Kohlswa Ironworks. It contains 0.10 per cent of carbon, but is otherwise of remarkable purity, as shown by the following analysis, performed at the Kohlswa laboratory:

Carbon	Silicon	Manganese	Phosphorus	Sulphur
0.10	0.14	0.03	0.26	0.007

Delivered as rolled wire 5.2 mm. in diameter, it was further drawn down to the diameter mentioned of 1.01 mm. at the wire works of the Nya Garphytte Fabriks Aktiebolag, Latorps Bruk.

Since for the special control Series III a thinner wire was desirable, the author drew the wire further in an ordinary drawing-plate. On this occasion the apparently very interesting observation was made that this material —obviously on account of its great purity—could be directly drawn through the finest hole of the plate, 0.23 mm., and further in sapphire holes to 0.09 mm., without the slightest annealing and without any real hardness being produced by this severe cold-working. This fact

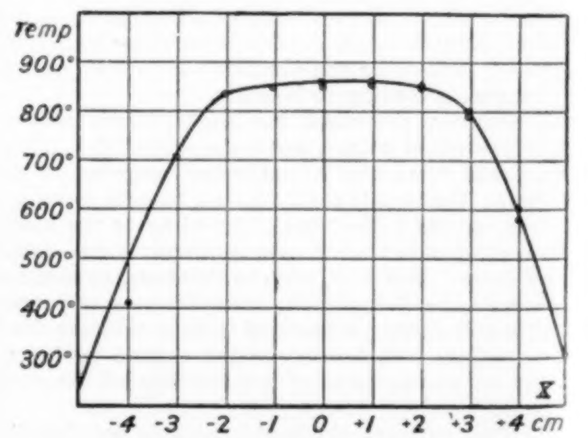


FIG. 2—TEST CURVES

seems to prove that iron of a high state of purity, even at 0.10 per cent carbon, has considerably more "liquid inner friction," and considerably less "solid inner friction,"[10] than has been generally believed, even in view of the extremely high mechanical deformability of pure iron in A3, found by the author two years ago.[11]

It can be questioned whether this extremely high soft-

[8]Journ. of the Iron and Steel Inst., 1912, No. 11, p. 242; 1914, No. 1, p. 407.

[9]Ibid, 1915, No. 1, p. 199; Sci Reports of the Tohoku Imperial Univ., 1915, vol. 1., p. 169.

[10]Cf. H. I. Hannover, Mekanisk Teknologi, 11, 3 Ed., Copenhagen, 1915, footnote, p. 68.

[11]Journal of the Iron and Steel Institute, 1914, No. 1, p. 431.

ness"[12] of pure low-carbon iron is favorable to the well-known Beilby hard amorphous state theory.

Since it was highly desirable to make experiments by this method on still purer iron wire, which was, however, not available, the following method was tried and found to be practicable. A small thin specimen of the extremely pure electrolytic iron used by Drs. J. E. Stead and H. C. H. Carpenter,[13] kindly presented by Professor Carpenter, was carefully rounded off at the corners, after which a strip about 1.3 mm. broad and of sufficient length was cut off round the piece. This strip was straightened and strengthened—especially against oxidation—by forming it into a U section.

Experimental Results

Determinations at a given temperature showed no difference when made during heating or cooling of the furnace, as was to be expected.

A blank experiment was performed with a 1-mm. copper wire in the same interval of temperature as that

Temperature T, Degrees Centigrade	Deviation U in Millimetres	Mean
642	+ 1.9 − 0.3	1.1
708	5.1 1.2	3.2
75	18.7 18.5	18.6
810	21.2 23.4	22.3
854	64 61	63
873	84 88	86
898	....	94
925	99 102	100.5
950	....	110

finally used. After a first annealing no deviation of the galvanometer whatever was obtained, which agrees with the known absence of allotropic change in this metal.

The result of the first series (1) of experiments on the Kohlswa iron wire is given in Table I.

These determinations are reproduced graphically in Fig. 3 as small circles.

It will be seen that this thermo-electric hysteresis effect is already sensible somewhat above 600 deg.; other determinations not given here seem to corroborate this lower limit, though in a somewhat uncertain manner. The effect increases with increasing velocity, as it seems, up to about 875 deg., where an increase at constant rate sets in, corresponding with the γ range. It may be said that A3 is clearly shown by a discontinuity.

This first series, however, is not sufficiently accurate to enable it to be decided whether between 600 deg. and 875 deg. the increase is a continuous one, or whether there might be a discontinuity at A2 (768 deg.). A second series (II) was carried out between 700 deg. to 800 deg., marked by vertical crosses. The observed values do not show any discontinuity.

A third series (III) was performed on the same material drawn out to 0.30 mm. wire. Owing to the fact that the stretching weights were only 20 grams, the motion was less regular than before. It will be seen, however, that the observed points (diagonal crosses) do not differ much from previous observations. This indicates that the slight oxidation which occurred has no sensible effect on the observations, which also seems probable from other points of view, and that the diameter has but a slight influence.

A fourth series (IV) was executed on the strip of pure electrolytic iron, as mentioned above (shown by full circles). In this case, as might be expected from the known influence of impurities, the effect is generally much less strong than with the 0.10 per cent carbon iron; the difference is less pronounced at the highest temperature, where, of course, the γ state prevails even in the absence of every trace of impurity. In any case, in a qualitative way, the effect is the same.

It was rather interesting to find, consistently with the impurity effect just mentioned, that while for the iron with 0.10 per cent carbon the speed of the motion had but very little influence, for the purest iron the effect was stronger if the speed exceeded the normal value.

The total appearance of the curves is similar to the well-known dilatation curves (Charpy and Grenet), inasmuch as both obviously belong to the allotropy Type II*a*. The new determinations have the special interest of proving the existence of molecular changes, demanding a definite time to occur.

It is scarcely necessary to point out that these new facts give additional support to the theory expounded by the author, that a continuous molecular change does

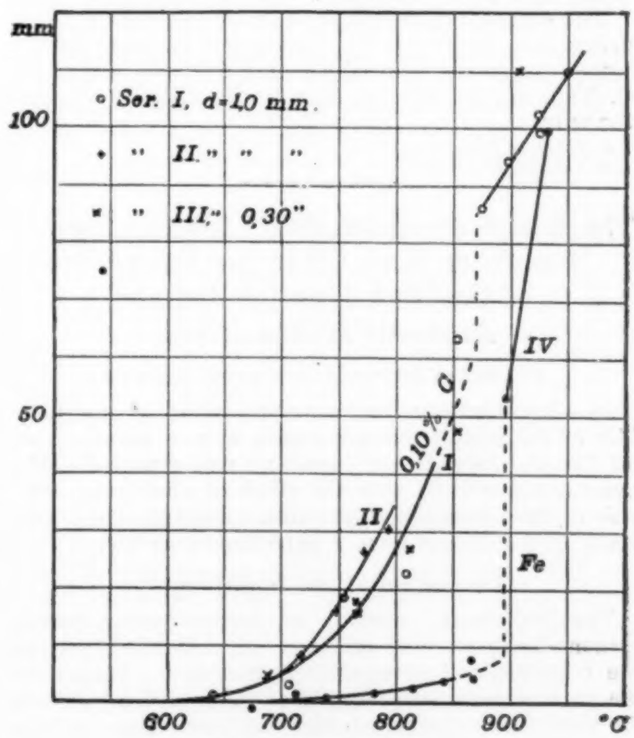


FIG. 3—TEST CURVES

occur in the alpha-phase at temperatures up to A3, or, in other words, that the alpha-phase has an increasing solubility for the molecules, or atoms, which are to be considered as characteristic for the gamma-phase. Whereas, A3 is a true allotropic point, where two phases co-exist, this is not the case with A2.

[12] In this connection it might be pointed out how important it is that laboratories, equipped with good technical-mechanical appliances, should be at the disposal of scientific men, offering the possibility of autoptic observations. Exactly the same 1-millimetre iron wire, on the request of Dr. Bengt Beckman, Upsala, was sent by me to the Cryogene laboratory, of Leyden, where it was to be used for researches by Professor H. Kamerling Onnes and Dr. Beckman. This wire was drawn by Heraeus in Hanau to a diameter of 0.1 millimetre. If, in Hanau, some observations were made of the very peculiar viscosity properties of this iron, they apparently have not been reported to these authors (Comm. Phys. Labor., Leyden, No. 132, p. 7, 1913). At the Garphytte Works, the manager, Mr. G. Tidholm, found that this iron was so excellent for drawing purposes that inquiries were made as to whether it could be obtained in commercial quantities. It was only after having gained personal experience in the fine drawing of this material that the author could get some idea of this remarkable occurrence of "liquid inner friction" in iron which, according to a private communication, was likewise unknown to Professor Hannover, to whom a sample was sent.

[13] Journal of the Iron and Steel Institute, 1913, No. 11, p. 119.

On the other hand (and this might be the principal result), it has been found that a local heating, traveling with definite speed, constitutes a method which may be of value for allotropy investigations, not only for iron, but for other metals or alloys as well.

As for iron it would be highly desirable to use pure iron wire, of sufficient length and diameter, and to repeat the determinations with greater accuracy, and with greater velocity, than it was possible to do here, on account of want of material.

Summary

1. The principle is described, and an experimental arrangement is shown for a method of determining an effect of thermo-electrical hysteresis (Barrett) in metals, which are characterized by allotropy (both two-phase and single-phase). The metal to be investigated is moved, in the form of a wire, with constant speed through a small furnace, the maximum temperature T of which is known; between the free ends of the wire an electromotive force may appear, if molecular changes occur in the metal at temperatures below T.

2. It has been found that this thermo-electric hysteresis effect, for iron, shows a very marked discontinuity at A3 (Fig. 3). Above this point the effect is very strong, following a straight line, but it is also very considerable at lower temperatures, even as low as about 600 deg.

As might be expected, the effect is considerably stronger in iron with 0.10 per cent carbon than in carbonless iron.

No discontinuity corresponding to A2 could be found.

3. These experimental results give additional support to the theory of the allotropy of iron, as expounded by the author. However their accuracy is not very high, and it is desirable that they should be repeated, especially on homogeneous solid wire of purest iron.

The author has the pleasure of acknowledging his indebtedness to Mr. L. U. Lingberg, Kohlswa, for the valuable specially selected research material, and to Mr. G. Tidholm, Garphyttan, for his kindness in drawing the wire.

University of Stockholm,
Stockholm, Sweden.

The Effect of Aluminium Chloride Upon a Naphthene Base Oil in the Formation of Gasoline, Unsaturated and Aromatic Hydrocarbons

BY GUSTAV EGLOFF AND ROBERT J. MOORE

In a previous communication[1] the effect of the chlorides of the metals and non-metals upon a paraffin base oil for the formation of gasoline was reported. The present paper deals with the effect of aluminium chloride in the formation of gasoline, unsaturated and aromatic hydrocarbons from a naphthene base oil[2].

Discussion of the Naphthenes

The naphthene, alicyclic or polymethylene hydrocarbons lie in physical and chemical properties between the aliphatic and aromatic hydrocarbons. They have the general empirical formula of C_nH_{2n} and are isomeric with the olefin seried hydrocarbons. But, in contradistinction to the olefins they are saturated ring compounds. The physical constants of specific gravity and refractive index of naphthenes lie between the values of the aliphatic and aromatic compounds for those individual naphthenes studied. In chemical behavior they resemble more nearly the paraffin than the aromatic hydrocarbons toward the common reagents such as sulphuric, nitric and halogen acids and the halogens themselves.

It has been known for a long time that in Russian and some American petroleum oils, fractions existed which, although having the same boiling points as the paraffin hydrocarbons, gave a higher specific gravity and the empirical formula of C_nH_{2n}. Although the empiric formula would indicate olefins, upon treatment with acids or halogens no addition compounds were formed. Furthermore, they did not act like aromatic hydrocarbons with the usual reagents. A number of these compounds have been isolated which neither reacted in the class of aliphatic or aromatic hydrocarbons and which gave the same physical and chemical properties as the synthesized polymethylenes of the hexahydrobenzene type or polycyclicmethylenes. Maberry[3] and others have isolated compounds of high boiling points and specific gravity giving upon hydrogen and carbon determination the formula C_nH_{2n}, but of whose constitution very little is known.

Naphthenes lack multiple bonds but have a closed carbon chain, one of the simplest being cyclohexane or hexamethylene, C_6H_{12}. Sabatier and Senderens[4] readily converted aromatic hydrocarbons into naphthenes, as illustrated, by passing vapors of benzene and hydrogen over nickel: $C_6H_6 + 3H_2 \rightleftarrows C_6H_{12}$.

Likewise with elimination of hydrogen from hexahydrobenzene or cyclohexane, benzene may be formed. Zelinsky[5] performed this experiment with palladium at 300 deg. C. but found that at 100 deg. to 110 deg. C. the reverse reaction took place which indicates the ready reversibility of the reaction. The ready facility of the decomposition of a naphthene oil has been noted by Brooks and Humphrey[6] and by others, a full bibliography of which is given in Engler-Höfer, "Das Erdöl." The ease with which the naphthenes may be decomposed and converted into hydrocarbons of widely different characteristics seemed to the authors to make them particularly adaptable to catalytic conversion work. It was with the endeavor of obtaining some light upon this point and to augment a general study of the aluminium chloride reaction on various type oils that the following work was undertaken:

Derivation of the Oil Used

The fractions used in the following experiments were derived from a naphthene base oil. The distillation analysis of the original oil from which the fractions were made analysed as given in Table 1. The distillation was carried on in a standard 200 c.c. Engler flask.

TABLE 1.

Specific gravity ....0.878—15.5 deg. C.

Temperature, Deg. C.	Per Cent by Volume	Specific Gravity 15.5 Deg. C.
175 to 200	1.8	.....
200 to 225	2.9	.....
225 to 250	4.5	0.842
250 to 275	6.3	0.844
275 to 300	6.2	0.848
300 to 325	3.5	0.850
325 to 350	4.9	0.854

Twenty-five gallons of this oil was distilled by steam, direct heating and vacuum. The first four fractions of the twenty-five gallons were made when 4 per cent for each cut came over. The fifth fraction was 8 per cent of the twenty-five gallons. Fractions three, four and

[1] Egloff and Moore, Met. and Chem. Eng., 15, 67, 1916.

[2] A paper will appear shortly by the authors giving the results of the action of aluminium chloride upon the individual aromatic hydrocarbons of the benzene series.

[3] Maberry Proc. Amer. Acad. 37, 565, 1902. For full bibliography see Engler-Höfer, Das Erdöl, 316, 1913.

[4] Sabatier and Senderens, Ann. Chim, Phys. 8, 4, 458, 1905.

[5] Zelinsky, Berichte 44, 3121, 1911.

[6] Brooks and Humphrey, Jour. Amer. Chem. Soc. 38, 393, 1916.

five were distilled in vacuum, so as to avoid possible decomposition of the oil. The highest fraction number six was redistilled with steam and direct heating at atmospheric pressure. With these fractions eliminated, the remaining 72 per cent of oil were enhanced in value as a lubricant of high flash and fire, low cold test and high viscosity at working temperatures; the latter property being usually recognized as an attribute of the naphthene hydrocarbons.

The flash point and fire test of the six fractions were taken. The flash point test was determined by means of the open cup method. Table 2 gives the data of the two sets of values for the flash point and fire test.

TABLE 2.

	Flash Point, Deg. F.	Fire Test, Deg. F.
Fraction 1	97	116
Fraction 2	138	155
Fraction 3	174	195
Fraction 4	200	230
Fraction 5	230	265
Fraction 6	280	305

The procedure adopted for the determination of unsaturated hydrocarbons was by use of c. p. sulphuric acid of specific gravity 1.84. The per cent of acid, the measuring cylinder and centrifuge used in the manipulation has already been given in detail.[7]

The method of nitrating the distillation cuts after the determination of olefins was by adding a nitration mixture consisting of one part 1.42 nitric acid to two parts of 1.84 sulphuric acid to the mixture of sulphonated and unsulphonated oil after cooling to zero deg. C. The mixture was then shaken thoroughly after the addition of the nitric-sulphuric acid mixture and cooled to zero for each addition. The unsulphonated and unnitrated residue oil was pipetted off, neutralized with a 10 per cent sodium hydroxide solution, washed with water and dried over fused calcium chloride. The number of c. c. absorbed read off on the measuring cylinder, and the results calculated to per cents in the cut.

The individual distillation, specific gravity and refractive index analysis of the six oils are given in Table 3. The specific gravity of the original six oils increased from 0.836 in oil one to 0.849 in oil six, while the refractive index ranged from 1.46150 to 1.46536. The temperature of the first drop of distillate appeared at the end of the condensor for the six oils from 145 deg. C. to 290 deg. C. The per cent by volume, specific gravity and refractive index values are compared between the six distillations of the oils as shown in Table 3.

The per cent of unsaturation, per cent nitrated and the per cent of remaining hydrocarbons unattacked by the acids of the distillation cuts of the original oils are given in Tables 4, 5 and 6. The maximum per cent of unsaturation was found in oil 3 of 8.3 per cent and a minimum was found in oil 3 of 1 per cent. From the data it is apparent that as the temperature of the distillation cuts increases, the percent of unsaturation decreases to a minimum in the distillation cut of 275 deg. to 300 deg. C. in oil 6.

The per cent of nitrated hydrocarbons in the distillation cuts of the six oils is given in Table 5. The per cent of nitratable hydrocarbons reached a maximum of 54.9 per cent in distillation cut 150 deg. to 175 deg. C. The per cent decreases steadily in the first distillation cut of each oil from 54.9 per cent in oil No. 1 to 13 per cent in oil No. 6. The high per cents of nitratable hydrocarbons in the original oils has called for an investigation of the nitro derivatives of the hydrocarbons present in the oil.[8]

The per cent of hydrocarbons unattacked by sulphuric acid and nitric acid mixture from distillation cuts of the original oils is given in Table 6. It is to be noted that the per cent of unattacked hydrocarbons increases with increase of temperature of the distillation cuts. The minimum of unattacked hydrocarbons, 38.5, appears in oil No. 1 from the cut between 150 deg. to 175 deg. C., 54.9 per cent of this cut was nitrated, indicating a high per cent of aromatic hydrocarbons present.

In Table 7 the total per cent of sulphonated and nitrated hydrocarbons from the six oils is expressed. The distillation cut 150 deg. to 175 deg. C. in oil 1 gave a per cent of 61.5 for the total sulphonated and nitrated hydrocarbons. The per cent of sulphonated and nitrated hydrocarbons in the first distillation cut of each oil decreases from 61.5 in oil 1 to 14 per cent in oil 6. This indicates the increasing stability of the hydrocarbons toward the reagents sulphuric and nitric acids as the boiling points increase.

The specific gravity of the distillation cuts of the original six oils after sulphonation, nitration and washing in oil 1, 4 and 6 decreased, and increased in the other three oils. The experimental data in Table 8 shows that the reaction of aluminium chloride on the six oils used, derived from a napthene base oil, first increases and then decreases the specific gravity of the distillation cuts after sulphonation and nitration.

The index of refraction shows a similar series of values in Tables 9 and 10.

The distillation cuts of the unattacked hydrocarbons were cooled to a temperature of from minus 6 to 10 deg. C., and showed no evidence of paraffins, either as the familiar bloom or by separating out.

The character of the foregoing results as based upon the distillation, specific gravity, refractive index, sulphonation and nitration, and cooling the unattacked hydrocarbons to minus 6 to 10 deg. C. indicates clearly the naphthenic character of the starting oils for the following study of the behavior of aluminium chloride in the formation of gasoline, unsaturated and aromatic hydrocarbons:

Summary as to the Character of Oils Used

1. Twenty-five gallons of a naphthene base oil were distilled by heat, steam and part in vacuum. The first four cuts being 4 per cent each, the fifth representing 8 per cent and the sixth cut 4 per cent of the starting twenty-five gallons.

2. The distillations were made in 25 deg. C. cuts, the per cent by volume, the specific gravity, refractive index, the per cent of unsaturation, the per cent of nitratable hydrocarbons in the cuts, and the per cent of unattacked hydrocarbons by sulphuric and nitric acid have been determined.

3. The specific gravities of the six oils range between 0.836 and 0.849. The refractive index values increased from 1.46150 to 1.46536. From the end of the condensor, the first drop in oil 1 was found to be 145 deg. C., which value increased to 290 deg. C. in oils 1 to 6. The distillation cuts gave gradual increase of the specific gravity and refractive index from oil 1 to 6.

4. The maximum of unsaturation was found in oil 3 of 8.3 per cent in cut 200 deg. to 225 deg. C., and a minimum of 1 per cent in oil 6.

[7] Egloff and Twomey, Met. and Chem. Eng. 14, 247, 1916.

[8] An investigation of the nature and chemical constitution of the nitro-derivatives of the alicyclic hydrocarbons present in the various high boiling distillation cuts of the naphthene base oil is now being conducted in this laboratory.

5. The maximum of nitrated hydrocarbons was found in oil 1 of 54.9 per cent in cut 150 deg. to 175 deg. C., with a minimum in oil 6 of 9.2 per cent in the residue.

6. Oil 6 gave a maximum of 87.7 per cent of unattacked hydrocarbons by sulphuric and nitric acid in the residue, with a minimum of 38.5 per cent in the cut 150 deg. to 175 deg. C in oil 1.

7. A total of 61.5 per cent of unsaturated and nitrated hydrocarbons in the distillation cut 150 deg. to 175 deg. C. in oil 1 was found. The minimum in oil 6 of 12.3 per cent was determined in the residue.

8. The specific gravity and refractive index of the distillation cuts after sulphonation, nitration and washing gave irregular results in the values of the two physical constants.

9. The distillation, specific gravity, refractive index, sulphonation, nitration and cooling to minus 6 to 10 deg. C., which latter test showed no signs of bloom or separation of paraffins, all of these tests indicate clearly the naphthenic characteristics of the starting six oils.

Table 3.

Distillation analysis of the original six oils.

Spec. grav.	0.836	0.840	0.843	0.845	0.848	0.849
Ref. index	1.46150	1.46170	1.46288	1.46308	1.46467	1.46536
First drop	145 C.	174 C.	203 C.	230 C.	251 C.	290 C.
Fraction No.	1	2	3	4	5	6
Temperature, Deg. C.	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume
to 150	1.5	....	....	....	....	....
150 to 175	48.5	0.8	....	....	....	....
175 to 200	29.5	49.0	....	....	....	....
200 to 225	...	32.8	35.7	....	....	....
225 to 250	...	....	36.9	35.0	....	....
250 to 275	...	....	16.8	38.8	44.0	....
275 to 300	...	....	....	12.3	35.5	18.5
300 to 325	...	....	....	....	2.0	....
300 to 350	...	....	....	....	....	23.0
Residue	19.0	16.3	9.1	13.1	17.3	56.0
Loss	1.5	1.1	1.5	0.8	1.2	2.5

Specific Gravity of the Distillation Cuts of Oils One to Six.

	Sp. Gr.	Sp. Gr.	Sp. Gr.	Sp. Gr.	Sp. Gr.	Sp. Gr
150 to 175	0.831	.....	.....	.....	.....	.....
175 to 200	0.837	0.839	.....	.....	.....	.....
200 to 225	....	0.841	0.841	.....	.....	.....
225 to 250	....	.....	0.844	0.844	.....	.....
250 to 275	....	.....	0.845	0.844	0.847	.....
275 to 300	....	.....	.....	0.844	0.847	0.845
300 to 350	....	.....	.....	.....	....	0.846
Residue	0.845	0.845	0.851	0.849	0.853	0.851

Refractive Index of the Distillation Cuts of Oils One to Six.

	Ref. Ind.	Ref. Ind.	Ref. Ind.	Ref. Ind.	Ref. Ind.	Ref. Ind.
150 to 175	1.46081	......	......	......	......	......
175 to 200	1.46062	1.46199	......	......	......	......
200 to 225	......	1.46119	1.46198	......	......	......
225 to 250	......	......	1.46160	1.46248	......	......
250 to 275	......	......	1.46297	1.46219	1.46418	......
275 to 300	......	......	......	1.46328	1.46409	1.46337
300 to 350	......	......	......	......	......	1.46368
Residue	1.46239	1.46249	1.46594	1.46536	1.46724	1.46605

Table 4.

The percent of unsaturation in the distillation cuts of the original six oils.

Fraction No.	1	2	3	4	5	6
Temperature deg. C.	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume
150 to 175	6.6	....	....	....	....	....
175 to 200	5.3	7.0	....	....	....	....
200 to 225	...	4.3	8.3	....	....	....
225 to 250	...	....	4.2	5.4	....	....
250 to 275	...	....	5.5	3.3	2.6	....
275 to 300	...	....	....	1.7	1.6	1.0
Residue	3.2	4.7	5.2	3.6	4.8	3.1

Table 5.

The percent of nitrated hydrocarbons in the distillation cuts of the original six oils.

Fraction No.	1	2	3	4	5	6
Temperature deg. C.	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume
150 to 175	54.9	....	....	....	....	....
175 to 200	40.9	42.0	....	....	....	....
200 to 225	...	31.4	28.3	....	....	....
225 to 250	...	....	21.3	15.9	....	....
250 to 275	...	....	13.9	15.0	14.8	....
275 to 300	...	....	....	14.9	20.3	13.0
Residue	20.9	11.1	22.4	13.2	11.1	9.2

Table 6.

The percent unattacked by sulphuric acid, and sulphuric and nitric acid mixture from the distillation cuts of the original oils.

Fraction No.	1	2	3	4	5	6
Temperature deg. C.	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume
150 to 175	38.5	....	....	....	....	....
175 to 200	53.8	51.0	....	....	....	....
200 to 225	...	64.3	63.4	....	....	....
225 to 250	...	....	74.5	78.7	....	....
250 to 275	...	....	80.6	81.7	82.6	....
275 to 300	...	....	....	83.4	78.1	86.0
Residue	75.9	84.2	72.4	83.2	84.1	87.7

Table 7.

The total percent of unsaturated and nitrated hydrocarbons in the distillation cuts of the original six oils.

Oil No.	1	2	3	4	5	6
Temperature deg. C.	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume	Percent Volume
150 to 175	61.5	....	....	....	....	....
175 to 200	46.2	49.0	....	....	....	....
200 to 225	...	35.7	36.6	....	....	....
225 to 250	...	....	24.5	21.3	....	....
250 to 275	...	....	19.4	18.3	17.4	....
275 to 300	...	....	....	16.6	21.9	14.0
Residue	24.1	15.8	27.6	16.8	15.9	12.3

Table 8.

The specific gravity of the distillation cuts of the original six oils after sulphonation, nitration and washing.

Oil No.	1	2	3	4	5	6
Temperature deg. C.			—Specific Gravity—			
150 to 175	0.818	....	....	....	....	....
175 to 200	0.832	0.835	....	....	....	....
200 to 225	....	....	0.845	....	....	....
225 to 250	....	....	0.860	0.849	....	....
250 to 275	....	....	....	....	0.842	....
275 to 300	....	....	....	....	....	0.846

Table 9.

The refractive index of the distillation cuts of the original six oils after sulphonation, nitration and washing.

Oil No.	1	2	3	4	5	6
Temperature deg. C.			—Refractive Index—			
150 to 175.	1.45071	......	......	......	......	......
175 to 200.	......	1.45321	......	......	......	......
200 to 225.	......	1.45471	1.45361	......	......	......
225 to 250.	......	......	1.45581	1.45691	......	......
250 to 275.	......	......	1.45531	1.45571	1.45701	......
275 to 300.	......	......	......	1.45561	1.45571	1.45711
Residue	1.45571	1.45561	1.45621	1.45841	......	1.46060

Experimental Procedure

In each experiment a charge of 300 c.c. of the oil was taken and 10 per cent by weight of aluminium chloride added in a Kjehldahl flash of 500 c.c. capacity to which was attached a 24-in. Liebig condenser. The temperature in the flask was maintained below 100 deg. C. for a period of twelve hours for each experiment. Whatever hydrocarbons boiling below 100 deg. C. were formed during this period of time condensed and were removed from the sphere of the reaction.

After twelve hours the residue in the flask was treated with a solution of 10 per cent of sodium hydroxide to clear the residue of the aluminium chloride present, filtered, washed and then dried with calcium chloride. The same procedure was carried out for the distillate, which came over during the twelve hours. The distillate and residue after drying were mixed and the volume, specific gravity and refractive index taken of the converted oil. In no case was there a heavy pitch-like residue left after the reaction such as is usually obtained from a paraffin base oil.

The method of analysis of each oil was by means of fractional distillation, specific gravity and refractive index, sulphonation and nitration. The distillations were made by means of a 300 c.c. round-bottom flask a Glinsky distilling head. The cuts were made by refractionating three times[a] to 95 deg. C. (benzene cut); 95 deg. to 120 deg. C. (toluene cut); 120 deg. to 150 deg. C. (xylene cut) and single fractionating for every

[a] Rittman, Twomey and Egloff, Met. and Chem. Eng., 13, 682, 1915.

25 deg. C. above 150 deg. C. in a standard 200 c. c. Engler flask until cracking of the oil took place from simple distillation at atmospheric pressure. This was noted as the temperature at which the mercury thread fell rapidly, although more heat was applied, which indicated lower boiling point hydrocarbon formation.

The specific gravity was determined by means of a Westphal balance having a plummet displacement of 1 c.c. at 15.5 deg. C. The refractive indices were determined by means of a Pulfrich refractometer at 20 deg. C.

Experimental Data

The experimental data are brought out in the following order by means of tables and graphs.

Table 10. The distillation analysis, specific gravity and refractive index of oils 1 to 6 compared with the recovered oil after reaction with aluminium chloride.

Table 11 and Fig. 1. The effect of aluminium chloride on the per cent of recovered oil, the specific gravity and refractive index of the recovered oil.

Table 12. The comparison of the effect of aluminium chloride on the distillation analysis of the six fractions.

Table 13. The effect of aluminium chloride on the specific gravity of the distillation cuts of the six fractions of a naphthene base oil.

Table 14. The effect of aluminium chloride on the refractive index of the distillation cuts of the six fractions of a naphthene base oil.

Table 15 and Fig. 2. The effect of aluminium chloride on the formation of gasoline from the six fractions on the basis of recovered oil.

Table 16 and Fig. 3. The effect of aluminium chloride on the formation of gasoline and specific gravity of the gasoline from the six fractions on basis of the oil used for production.

Table 17 and Fig. 4. The formation of benzene, toluene, and xylene from the action of aluminium chloride on the six oils on the basis of per cent in the recovered oil.

Table 18 and Fig. 5. The formation of benzene, toluene and xylene from the action of aluminium chloride on the six oils on basis of oil used for production.

Table 19. The specific gravity of the benzene, toluene and xylene cuts resulting from the aluminium chloride conversion of the six oils.

Table 20. The per cent of unsaturation in the distillation cuts after conversion of the six oils.

Table 21. The per cent nitrated in the distillation cuts after conversion of the six oils.

Table 22. The comparison of the per cent of unsaturation, per cent nitrated, and per cent unattacked by acids of the distillation cuts from the converted oils.

Table 23. The refractive index of the distillation cuts of the converted oil after sulphonation, nitration and washing.

Table 24. The specific gravity of the distillation cuts of the converted oil after sulphonation, nitration and washing.

TABLE 10.

The distillation analysis, specific gravity and refractive index of oils one to six compared with recovered oil after reaction with aluminium chloride.

Oil No. 1.

Temp. deg. C.	Original Fraction Pct.Vol.	After $AlCl_3$ Treatm't Pct.Vol.	Original Fraction Sp.Gr.	After $AlCl_3$ Treatm't Sp.Gr.	Original Fraction Ref.Ind.	After Treatm't Ref.Ind.
To 95	....	4.6	....	0.754	......	1.41516
95 to 120	....	7.5	....	0.784	......	1.43078
120 to 150	1.5	20.7	....	0.812	......	1.44811
150 to 175	48.5	13.4	0.831	0.829	1.46081	1.45641
175 to 200	29.5	33.0	0.837	0.836	1.46062	1.45961
200 to 225	....	10.2	....	0.845	......	1.46515
225 to 250	....	4.8	....	0.855	......	1.47048
Residue	19.0	4.7	0.845	0.910	1.46239	1.51236
Loss	1.5	1.1	....	....	......	......

Oil No. 2.

Temp. deg. C.	Original Fraction Pct.Vol.	After $AlCl_3$ Treatm't Pct.Vol.	Original Fraction Sp.Gr.	After $AlCl_3$ Treatm't Sp.Gr.	Original Fraction Ref.Ind.	After Treatm't Ref.Ind.
To 95	....	4.5	....	0.771	......	1,42291
95 to 120	....	5.2	....	0.794	......	1.43552
120 to 150	....	13.8	....	0.814	......	1.44589
150 to 175	0.8	1.5	....	0.831	......	1.45621
175 to 200	49.0	26.0	0.839	0.833	1.46199	1.45671
200 to 225	32.8	25.9	0.841	0.837	1.46119	1.45741
225 to 250	....	13.5	....	0.839	......	1.45821
250 to 275	....	5.5	....	0.849	......	1.46506
275 to 300	....	1.8	....	0.870	......	1.47588
300 to 325	....	0.4	....	0.879	......	1.47598
325 to 350	....	0.5	....	....	......	1.48315
350 to 385	....	0.4	....	....	......	1.48930
Residue	16.3	0.5	0.845	0.950	1.46249	1.54520
Loss	1.1	0.5	....	....	......	......

Oil No. 3.

Temp. deg. C.	Original Fraction Pct.Vol.	After $AlCl_3$ Treatm't Pct.Vol.	Original Fraction Sp.Gr.	After $AlCl_3$ Treatm't Sp.Gr.	Original Fraction Ref.Ind.	After Treatm't Ref.Ind.
To 95	....	7.5	....	0.713	......	1.39139
95 to 120	....	9.1	....	0.761	......	1.41708
120 to 150	....	14.3	....	0.796	......	1.43784
150 to 175	....	1.0	....	0.824		1.45341
175 to 200	....	8.0	....	0.828	......	1.45391
200 to 225	35.7	17.5	0.841	0.831	1.46198	1.45471
225 to 250	36.9	18.3	0.844	0.833	1.46160	1.45481
250 to 275	16.8	8.8	0.845	0.837	1.46297	1.45811
275 to 300	....	4.5	....	0.844	......	1.46436
300 to 325	....	0.4	....	....	......	1.47176
325 to 350	....	0.3	....	....	......	1.47224
350 to 385	....	0.5	....	....	......	1.47450
Residue	9.1	9.1	0.851	0.920	1.46594	1.52034
Loss	1.5	0.7	....	....	......	......

Oil No. 4.

Temp. deg. C.	Original Fraction Pct.Vol.	After $AlCl_3$ Treatm't Pct.Vol.	Original Fraction Sp.Gr.	After $AlCl_3$ Treatm't Sp.Gr.	Original Fraction Ref.Ind.	After Treatm't Ref.Ind.
To 95	....	12.0	....	0.708	......	1.38884
95 to 120	....	13.3	....	0.760	......	1.41718
120 to 150	....	13.0	....	0.785	......	1.43178
150 to 175	....	2.0	....	0.804	......	1.44388
175 to 200	....	6.3	....	0.812	......	1.44710
200 to 225	....	7.7	....	0.820	......	1.45021
225 to 250	35.0	13.3	0.844	0.826	1.46248	1.45111
250 to 275	38.8	18.7	0.844	0.826	1.46219	1.45111
275 to 300	12.3	8.0	0.844	0.828	1.46328	1.45421
300 to 325	....	0.6	....	....	......	1.45531
325 to 350	....	0.1	....	....	......	1.45641
350 to 385	....	0.1	....	....	......	......
Residue	13.1	3.6	0.849	....	1.46536	1.46980
Loss	0.8	1.3	....	....	......	......

Oil No. 5.

Temp. deg. C.	Original Fraction Pct.Vol.	After $AlCl_3$ Treatm't Pct.Vol.	Original Fraction Sp.Gr.	After $AlCl_3$ Treatm't Sp.Gr.	Original Fraction Ref.Ind.	After Treatm't Ref.Ind.
To 95	....	17.3	....	0.697	......	1.38301
95 to 120	....	13.7	....	0.751	......	1.41065
120 to 150	....	16.3	....	0.782	......	1.42977
150 to 175	....	1.0	....	0.799	......	1.44700
175 to 200	....	1.3	....	0.814	......	1.44559
200 to 225	....	4.0	....	0.816	......	1.44731
225 to 250	....	5.4	....	0.818	......	1.44881
250 to 275	44.0	9.0	0.847	0.821	1.46418	1.44891
275 to 300	35.5	9.0	0.847	0.822	1.46409	1.44891
300 to 325	2.0	0.7	....	....	......	1.44951
325 to 350	....	0.5	....	....	......	1.44981
350 to 385	....	0.3	....	....	......	1.44991
Residue	17.3	20.0	0.853	0.834	1.46724	1.45071
Loss	1.2	1.5	....	....	......	......

Oil No. 6.

Temp. deg. C.	Original Fraction Pct.Vol.	After $AlCl_3$ Treatm't Pct.Vol.	Original Fraction Sp.Gr.	After $AlCl_3$ Treatm't Sp.Gr.	Original Fraction Ref.Ind.	After Treatm't Ref.Ind.
To 95	....	17.5	....	0.683	......	1.37819
95 to 120	....	12.0	....	0.742	......	1.40714
120 to 150	....	15.0	....	0.769	......	1.42170
150 to 175	....	0.5	....	0.785	......	1.43328
175 to 200	....	0.9	....	0.800	......	1.43885
200 to 225	....	3.0	....	0.810	......	1.44156
225 to 250	....	4.2	....	....	......	1.44498
250 to 275	....	7.1	....	....	......	1.44761
275 to 300	18.5	...	0.845	....	1.46337	1.45121
300 to 350	23.0	...	0.846	....	1.46368	......
Residue	56.0	...	0.851	....	1.46605	1.45561
Loss	2.5	...	....	....	......	......

TABLE NO. 11.

The effect of aluminium chloride on the percent of recovered oil, the specific gravity and refractive index of the recovered oil.

Oil Number	1	2	3	4	5	6
Percent Recovered	79.3	78.3	77.0	68.0	60.0	72.0
Specific Gravity	0.832	0.835	0.811	0.797	0.773	0.774
Refractive Index	1.45861	1.45921	1.44861	1.43855	1.42473	1.42655

TABLE NO. 12.

The comparison of the effect of aluminium chloride on the distillation analysis of the six oils.

Oil Number / Temperature deg C.	1	2	3	4	5	6
	—Per cent Volume—					
To 95	4.6	4.5	7.5	12.0	17.3	17.5
95 to 120	7.5	5.2	9.1	13.3	13.7	12.0
120 to 150	20.7	13.8	14.3	13.0	16.3	15.0
150 to 175	13.4	1.5	1.0	2.0	1.0	0.5
175 to 200	33.0	26.0	8.0	6.3	1.3	0.9
200 to 225	10.2	25.9	17.5	7.7	4.0	3.0
225 to 250	4.8	13.5	18.3	13.3	5.4	4.2
250 to 275	...	5.5	8.8	18.7	9.0	7.1
275 to 300	...	1.8	4.5	8.0	9.0	...
300 to 325	...	0.4	0.4	0.6	0.7	...
325 to 350	...	0.5	0.3	0.1	0.5	...
350 to 385	...	0.4	0.5	0.1	0.3	...
Residue	4.7	0.5	9.1	3.6	20.0	...
Loss	1.1	0.5	0.7	1.3	1.5	...

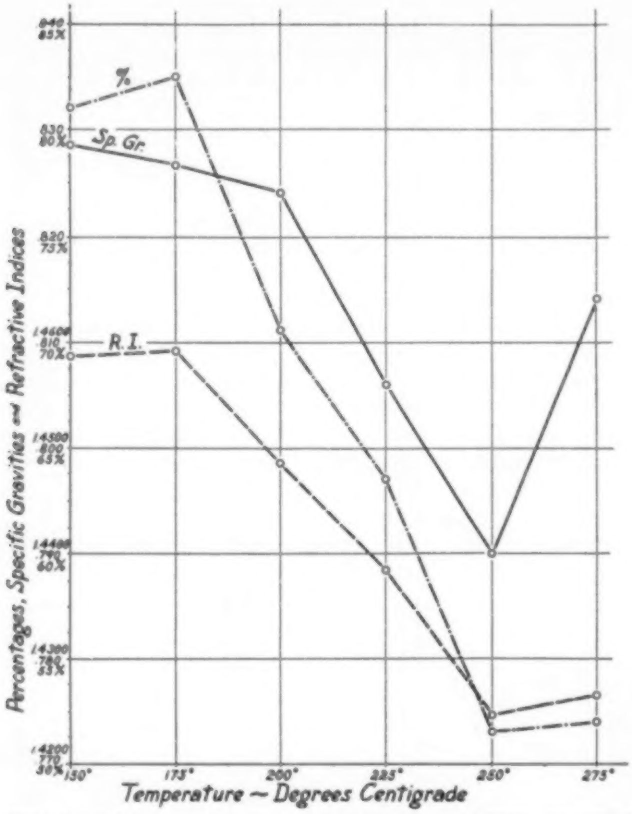


FIG. 1—THE EFFECT OF ALUMINIUM CHLORIDE ON THE PER CENT OF RECOVERED OIL, THE SPECIFIC GRAVITY AND REFRACTIVE INDEX OF THE RECOVERED OIL

TABLE No. 13.

The effect of aluminium chloride on the specific gravity of the distillation cuts of six fractions of a naphthene Base Oil

Fraction No. Temperature deg. C.	1 Sp. Gr.	2 Sp. Gr.	3 Sp. Gr.	4 Sp. Gr.	5 Sp. Gr.	6 Sp. Gr.
To 95	0.754	0.771	0.713	0.708	0.697	0.683
95 to 120	0.784	0.794	0.761	0.760	0.751	0.742
120 to 150	0.812	0.814	0.796	0.785	0.782	0.769
150 to 175	0.829	0.831	0.824	0.804	0.799	0.785
175 to 200	0.836	0.833	0.828	0.812	0.814	0.800
200 to 225	0.845	0.837	0.831	0.820	0.816	0.810
225 to 250	0.855	0.839	0.833	0.826	0.818	....
250 to 275	....	0.849	0.837	0.826	0.821	....
275 to 300	....	0.870	0.844	0.828	0.822	....
300 to 325	....	0.879	....	....	....	....
Residue	0.910	0.950	0.920	....	0.834	....

TABLE No. 14.

The effect of aluminium chloride on the refractive index of the distillation cuts of six fractions of a naphthene base oil.

Fraction No. Temperature deg. C.	1 Ref.Ind.	2 Ref.Ind.	3 Ref.Ind.	4 Ref.Ind.	5 Ref.Ind.	6 Ref.Ind.
To 95	1.41516	1.42291	1.39139	1.38884	1.38301	1.37819
95 to 120	1.43078	1.43552	1.41708	1.41718	1.41065	1.40714
120 to 150	1.44811	1.44589	1.43784	1.43178	1.42977	1.42170
150 to 175	1.45641	1.45621	1.45341	1.44388	1.44700	1.43328
175 to 200	1.45961	1.45671	1.45391	1.44710	1.44559	1.43885
200 to 225	1.46515	1.45741	1.45471	1.45021	1.44731	1.44156
225 to 250	1.47048	1.45821	1.45481	1.45111	1.44881	1.44498
250 to 275	......	1.46506	1.45811	1.45111	1.44891	1.44761
275 to 300	......	1.47588	1.46436	1.45421	1.44891	1.45121
300 to 325	......	1.47598	1.47176	1.45531	1.44951	......
325 to 350	......	1.48315	1.47224	1.45641	1.44981	......
350 to 385	......	1.48930	1.47450	......	1.44991	......
Residue	1.51236	1.54520	1.52034	1.46980	1.45071	1.45561

TABLE No. 15.

The effect of aluminium chloride on the formation of gasoline from the six fractions on the basis of recovered oil.

Fraction No.	1	2	3	4	5	6
Percent Gasoline	32.8	23.5	30.9	38.3	47.3	44.5

TABLE No. 16.

The effect of aluminium chloride on the formation of gasoline and specific gravity of the gasoline from the six fractions on basis of oil used for production.

Fraction No.	1	2	3	4	5	6
Percent Gasoline	26.0	18.4	23.8	26.0	28.4	32.1
Specific Gravity	0.781	0.801	0.765	0.748	0.741	0.726

TABLE No. 17.

The formation of benzene, toluene and xylene from the action of aluminium chloride on the six oils, on the basis of percent in the recovered oil.

Oil No. Percent—	1	2	3	4	5	6
Benzene	0.98	1.43	...	...	...	...
Toluene	2.96	2.38	2.02	2.85	2.05	1.03
Xylene	9.80	6.78	4.68	2.96	3.26	1.23

TABLE No. 18.

The formation of benzine, toluene and xylene from the action of aluminium chloride on the six oils on basis of oil used for production.

Oil No. Percent—	1	2	3	4	5	6
Benzene	0.78	1.11	...	...	...	...
Toluene	2.35	1.87	1.56	1.94	1.23	0.74
Xylene	7.80	5.31	3.60	2.01	1.36	0.88

TABLE 19.

The specific gravity of the benzene, toluene and xylene cuts resulting from the aluminium chloride conversion of the six oils.

Oil No.	1	2	3	4	5	6
Benzene cut	0.754	0.771	0.713	0.708	0.697	0.683
Toluene cut	0.784	0.794	0.761	0.760	0.751	0.742
Xylene cut	0.812	0.814	0.796	0.785	0.782	0.769

TABLE 20.

The per cent unsaturated hydrocarbons in the distillation cuts after conversion of the six oils.

Oil No. Temperature, Deg. C.	1	2	3	4	5	6
			Per Cent by Volume			
to 95	0.0	Trace	0.0	0.0	3.3	0.0
95 to 120	0.0	0.0	0.0	0.0	0.0	Trace
120 to 150	0.0	0.0	Trace	0.0	Trace	Trace
150 to 175	3.3	6.5	8.6	5.1	..	..
175 to 200	1.7	1.8	3.2	2.6	9.5	..
200 to 225	3.1	2.0	3.1	3.7	10.0	..
225 to 250	3.5	1.7	3.1	1.6	3.3	..
250 to 275	..	3.0	3.3	4.1	3.4	..
275 to 300	..	6.0	6.7	5.0	4.3	..
Residue	..	Sludge	Sludge	20.4	3.3	..

TABLE 21.

The per cent nitrated in the distillation cuts after conversion of the six oils.

Oil No. Temperature, Deg. C.	1	2	3	4	5	6
			Per Cent by Volume			
to 95	...	20.0	0.0	0.0	5.0	0.0
95 to 120	20.0	31.0	13.2	20.3	11.4	8.3
120 to 150	43.3	43.0	30.0	26.7	13.0	13.3
150 to 175	40.0	34.8	22.8	25.1	...	...
175 to 200	43.6	33.0	25.8	25.3	20.1	...
200 to 225	36.9	24.2	18.8	20.2	10.0	...
225 to 250	31.3	15.0	10.0	10.2	9.3	...
250 to 275	...	15.7	11.5	3.3	3.5	...
275 to 300	...	22.0	10.0	3.3	5.0	...
Residue	...	...	...	40.2	5.9	...

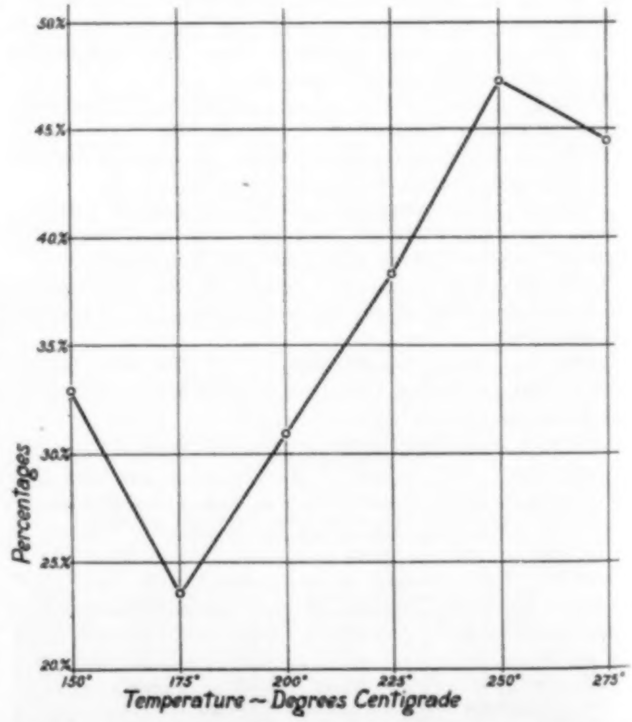


FIG. 2—THE EFFECT OF ALUMINIUM CHLORIDE ON THE FORMATION OF GASOLINE FROM THE SIX FRACTIONS ON THE BASIS OF RECOVERED OIL

TABLE 22.

The comparison of the per cent of unsaturated, per cent nitrated and per cent unattacked by acids of the distillation cuts from the converted oils.

Temperature, Deg. C.	Per Cent Unsaturated Orig. Fract.	Per Cent Unsaturated After $AlCl_3$ Treatment	Per Cent Nitrated Orig. Fract.	Per Cent Nitrated After $AlCl_3$ Treatment	Per Cent Unattacked Orig. Fract.	Per Cent Unattacked After $AlCl_3$ Treatment
Oil 1.						
to 95	..	0.0	...	...	...	...
95 to 120	..	0.0	...	20.0	...	80.0
120 to 150	..	0.0	...	43.3	...	56.7
150 to 175	6.6	3.3	54.9	40.0	38.5	53.4
175 to 200	5.3	1.7	40.9	43.6	53.8	58.3
200 to 225	..	3.1	...	36.9	...	60.0
225 to 250	..	3.5	...	31.3	...	65.2
250 to 275	..	..	...	...	...	...
275 to 300	..	..	...	...	...	...
Residue	3.2	..	20.9	...	75.9	...
Oil 2.						
to 95	..	Trace	...	20.0	...	80.0
95 to 120	..	0.0	...	31.0	...	69.0
120 to 150	..	0.0	...	43.0	...	57.0
150 to 175	..	6.5	...	34.8	...	58.7
175 to 200	7.0	1.8	42.0	33.0	51.0	65.2
200 to 225	4.3	2.0	31.4	24.2	64.3	73.8
225 to 250	..	1.7	...	15.0	...	...
250 to 275	..	3.0	...	15.7	...	...
275 to 300	..	6.0	...	22.0	...	...
Residue	4.7	Sludge	11.1	...	84.2	...
Oil 3.						
to 95	..	0.0	...	0.0	...	100.0
95 to 120	..	0.0	...	13.2	...	86.8
120 to 150	..	Trace	...	30.0	...	70.0
150 to 175	..	8.6	...	22.8	...	68.6
175 to 200	..	3.2	...	25.8	...	71.0
200 to 225	8.3	3.1	28.3	18.8	63.4	78.1
225 to 250	4.2	3.1	21.3	10.0	74.5	86.9
250 to 275	5.5	3.3	13.9	11.5	80.6	85.2
275 to 300	..	6.7	...	10.0	...	...
Residue	5.2	Sludge	22.4	...	72.4	...
Oil 4.					Per Cent	
to 95	..	0.0	...	0.0	...	100.0
95 to 120	..	0.0	...	20.3	...	79.7
120 to 150	..	0.0	...	26.7	...	73.3
150 to 175	..	5.1	...	25.1	...	69.8
175 to 200	..	2.6	...	25.3	...	72.1
200 to 225	..	3.7	...	20.2	...	76.1
225 to 250	5.4	1.6	15.9	10.2	78.7	88.2
250 to 275	3.3	4.1	15.0	3.3	81.7	92.6
275 to 300	1.7	5.0	14.9	3.3	83.4	91.7
Residue	3.6	20.4	13.2	40.2	83.2	39.4

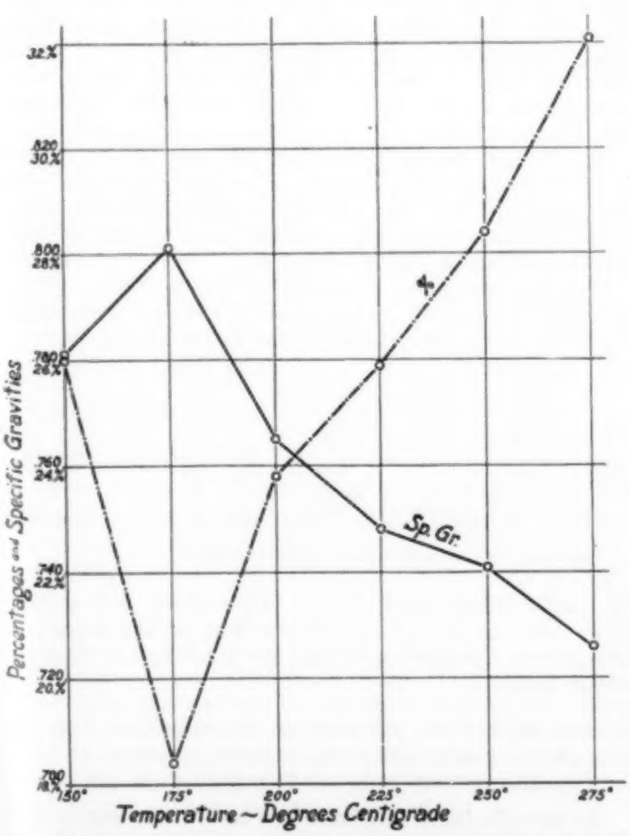


FIG. 3—THE EFFECT OF ALUMINIUM CHLORIDE ON THE FORMATION OF GASOLINE AND SPECIFIC GRAVITY OF THE GASOLINE FROM THE SIX FRACTIONS ON BASIS OF OIL USED FOR PRODUCTION

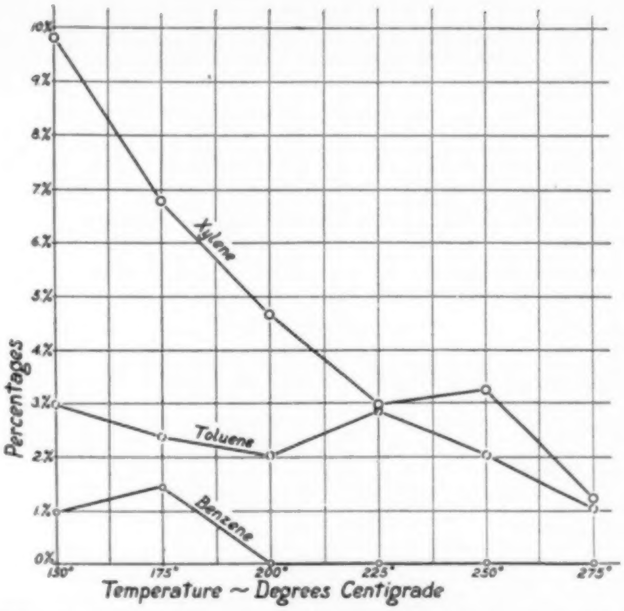


FIG. 4—THE FORMATION OF BENZENE, TOLUENE AND XYLENE FROM THE ACTION OF ALUMINIUM CHLORIDE ON THE SIX FRACTIONS ON THE BASIS OF PER CENT IN THE RECOVERED OIL

Temperature, Deg. C.	Per Cent Olefins Orig. Fract.	Per Cent Olefins After $AlCl_3$ Treatment	Per Cent Nitrated Orig. Fract.	Per Cent Nitrated After $AlCl_3$ Treatment	Unnitrated and Unsulphonated Orig. Fract.	Unnitrated and Unsulphonated After $AlCl_3$ Treatment
Oil 5.						
to 95	..	3.3	...	5.0	...	91.7
95 to 120	..	0.0	...	11.4	...	88.6
120 to 150	..	Trace	...	13.0	...	87.0
150 to 175	..	...	...	...	...	...
175 to 200	..	9.5	...	20.1	...	70.4
200 to 225	..	10.0	...	10.0	...	80.0
225 to 250	..	3.3	...	9.3	...	87.4
250 to 275	2.6	3.4	14.8	3.5	82.6	93.1
275 to 300	1.6	4.3	20.3	5.0	78.1	90.7
Residue	4.8	3.3	11.1	5.9	84.1	90.8
Oil 6.						
to 95	..	0.0	...	0.0	...	100.0
95 to 120	..	Trace	...	8.3	...	91.7
120 to 150	..	Trace	...	13.3	...	86.7
150 to 175	..	...	...	...	...	...
175 to 200	..	...	...	...	...	...
200 to 225	..	...	...	...	...	...
225 to 250	..	...	...	...	...	...
250 to 275	..	...	...	...	...	...
275 to 300	1.0	...	13.0	...	86.0	...
Residue	3.1	...	9.2	...	87.7	...

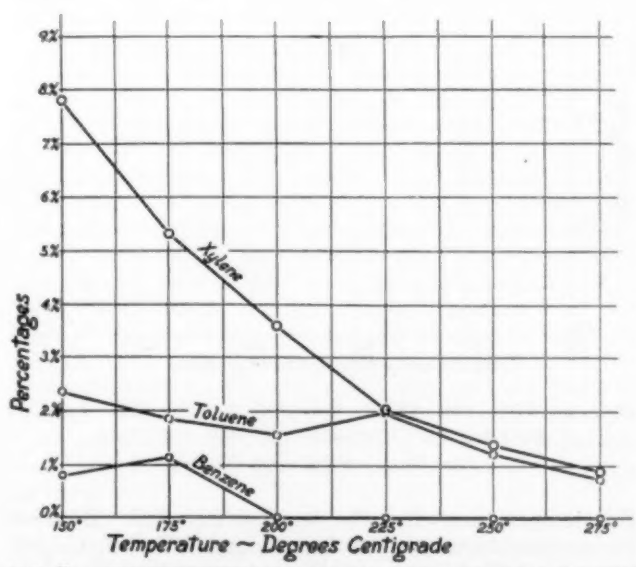


FIG. 5—THE PER CENT OF BENZENE, TOLUENE AND XYLENE FROM THE ACTION OF ALUMINIUM CHLORIDE ON THE SIX FRACTIONS ON BASIS OF OIL USED FOR PRODUCTION

TABLE 23.

The refractive index of the distillation cuts of the converted oil after sulphonation, nitration and washing.

Oil No.	2	3	4	5	6
Temperature, Deg. C.			Refractive Index		
to 95.....	1.42291	1.39139	1.38884	1.39128	1.37819
95 to 120.....	1.42422	1.41015	1.40985	1.40664	......
120 to 150.....	1.43219	1.42352	1.41898	1.42019	1.41766
150 to 175.....	1.44247	....	....	......	......
175 to 200.....	1.45011	1.44468	1.43633	......	......
200 to 225.....	1.45131	1.44751	1.44116	......	......
225 to 250.....	....	1.45271	1.44700	1.44600	......
250 to 275.....	1.45531	....	1.44801	1.44791	......
275 to 300.....	1.45891	....	1.44911	1.44801	......
Residue	....	....	....	1.45231	......

TABLE 24.

The specific gravity of the distillation cuts of the converted oil after sulphonation, nitration and washing.

Oil No.	2	3	4	5	6
Temperature, Deg. C.		Specific Gravity			
175 to 200...........	0.846	....	....	....	....
200 to 225...........	....	0.837	....	....	....
225 to 250...........	....	....	0.833	....	....
250 to 275...........	....	....	....	0.830	....
275 to 300...........	....	....	....	....	0.826

Discussion of Experimental Data

A. THE DISTILLATION ANALYSIS, SPECIFIC GRAVITY AND REFRACTIVE INDEX OF THE SIX OILS COMPARED WITH THE RECOVERED OIL AFTER REACTION WITH ALUMINIUM CHLORIDE

In each oil treated with aluminium chloride the reaction tended toward the formation of hydrocarbons of much lower boiling points, lower specific gravity and lower refractive index than in the original.

In oil 1, the per cent boiling below 150 deg. C. of the original was 1.5, while the per cent boiling below

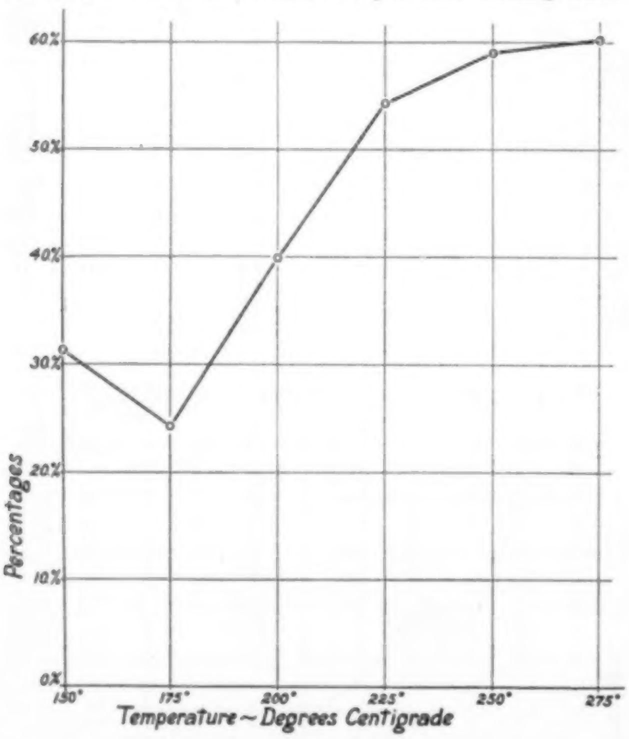


FIG. 6—THE PER CENT BOILING BELOW THE LOWEST BOILING CONSTITUENT OF THE ORIGINAL FRACTION AFTER CONVERSION

this temperature after the reaction was 32.8. Between the temperatures of 150 deg. C. and 175 deg. C. 48.5 per cent boiled betweeen these temperature limits in the original oil, while treatment of the fraction with aluminium chloride converted 35.1 per cent to higher and lower boiling point constituents. The reaction tended mainly in the direction of lower boiling point hydrocarbons.

Oil 2 originally yielded 0.8 per cent below 175 deg. C., while after treatment 25.0 per cent distilled over below this temperature. The specific gravity and refractive index of the distillation cuts after conversion of the fraction were found to be lower than the corresponding cuts of the original.

In oil 3 the 35.7 per cent boiling below 225 deg. C. was converted with the other fractions boiling above, to 57.4 per cent, a difference of 21.7 per cent. Although the starting oil gave a percentage of 72.6 boiling between the limits of 200 deg. and 250 deg. C., after reacting with aluminium chloride the per cent between these limits changed to 35.8 per cent, with a change of specific gravity and refractive index lower than the original oil.

Oil 4, after conversion, gave 54.3 per cent of hydrocarbons with boiling points below the lowest boiling constituent of the starting fraction. This amount of conversion came mainly from the cuts boiling between 225 deg. and 275 deg. C., of which 73.8 per cent of the fraction of the naphthene oil boiled between these temperature limits. Only 12.4 per cent of the converted oil boiled above the temperature of 275 deg. C., which indicates that this particular fraction under the conditions of the experiment went mainly to hydrocarbons of much lower volatility than the starting oil.

Oil 5, after conversion, gave 59 per cent below the temperature of 250 deg. C., whereas the original oil gave zero per cent. A change of 35 per cent occurred in the cut boiling between 250 deg. and 275 deg. C. after the aluminium chloride treatment. The cut between 275 deg. and 300 deg. C. gave a difference of 26.5 per cent after treatment. The differences in the per cent of the two cuts show conversion mainly toward the lower boiling point hydrocarbons and a very small per cent toward higher boiling point substances. The differences between the specific gravity and refractive index values are more marked in the conversion of oil 5 than in any of the previously described oils.

Oil 6 upon treatment with aluminium chloride gave a percentage of 60.2, boiling below the temperature of the lowest boiling point constituent of the original oil. The hydrocarbons are of a much lower volatility than any preceding converted oil.

The tabulation in Table 25 of the per cent of the mixture of paraffin, unsaturated, benzene and naphthene seried hydrocarbons boiling below the lowest boiling point constituent of the original oil, will give a clear idea as to the conversion due to the action of aluminium chloride upon the six fractions of a naphthene base oil.

TABLE 25.

Temperatures of lowest boiling constituent in the original fraction in degrees Centigrade....	150	175	200	225	250	275
Oil No.	1	2	3	4	5	6
Per cent boiling below the lowest boiling point constituent of the original oil after conversion..	31.3	24.3	39.9	54.3	59.0	60.2

The data are expressed graphically in Fig. 6.

B. THE EFFECT OF ALUMINIUM CHLORIDE ON THE PER CENT OF RECOVERED OIL, SPECIFIC GRAVITY, AND REFRACTIVE INDEX OF THE RECOVERED OIL

As the oils increased from one to five, the per cent of recovered oil decreased to a minimum of 60 per cent and then increased in fraction 6 to 72 per cent. The specific gravity of the recovered oil showed a maximum in fraction two of 0.835 and a minimum in fraction five

of 0.773. Fraction six increased slightly over fraction five giving a value of 0.774 for its specific gravity. The refractive index values paralleled the values for specific gravity indicating the additive property of the refractive index constant for hydrocarbons.[10] In Fig. 1 the data are expressed graphically.

C. THE EFFECT OF ALUMINIUM CHLORIDE ON THE PER CENT BY VOLUME OF THE CUTS OF THE SIX FRACTIONS OF THE NAPHTHENE BASE OIL

In the benzene cut to 95 deg. C. the per cent of the low boiling hydrocarbons increased from 4.6 per cent to 17.5 in going from oils one to six. The toluene cut 95 deg. to 120 deg. C. showed two minima, 5.2 per cent resulting from oil 2 and 12 per cent from oil six. The xylene cut 120 deg. to 150 deg. C., shows an alternate maximum and minimum. In the cut from 150 deg. to 175 deg. C. a very small percentage is to be noted with the exception of oil one, which would indicate a very small, if any, formation of the trimethyl benzenes. In the other distillation cuts no regularity is apparent in the percentages of the cuts in the recovered oil.

D. THE EFFECT OF ALUMINIUM CHLORIDE ON THE SPECIFIC GRAVITY OF THE DISTILLATION CUTS OF THE SIX FRACTIONS OF A NAPHTHENE BASE OIL

In the cut to 95 deg. C. the specific gravity is shown as a maximum of 0.771 in oil two. The cut shows two minima of 0.754 in oil one and of 0.683 in oil six.

In each cut up to 175 deg. C. the maximum specific gravity was found to be in fraction two. Between 175 deg. and 200 deg. C. the maximum is attained in fraction one and the specific gravity decreases in this cut from fraction one to six. In each converted fraction the specific gravity of the cuts increases as the distillation cuts increase in temperature with one exception, this is that the specific gravity of two cuts is the same in oil four. The distillation cut from 225 deg. to 250 deg. C. and the cut from 250 deg. to 275 deg. C. in oil four gave each a specific gravity of 0.826.

E. THE EFFECT OF ALUMINIUM CHLORIDE ON THE REFRACTIVE INDEX OF THE DISTILLATION CUTS OF THE SIX FRACTIONS OF A NAPHTHENE BASE OIL

The refractive index of oils, such as those under investigation is not only a simple physical constant to determine, requiring only a drop of liquid, but in addition furnishes a valuable criterion in judging the nature of the type of hydrocarbons present in the oils, in conjunction with the specific gravity, sulphonation and nitration of the various distillation cuts made.

Although the index of refraction is an additive property for each type of oil, similar in respects to the specific gravity, yet the refractive indices for the paraffin, aromatic and naphthene seried hydrocarbons are widely different in value. This may be seen in table 26,

TABLE 26.

	Boiling Point Range	Index of Refraction Average
Paraffins	68 deg. to 174 deg. C.	1.403
Naphthenes	80.0 deg. to 172 deg. C.	1.423
Aromatics	80.4 deg. to 167 deg. C.	1.501

based upon the average refractive indices of the three groups of hydrocarbons between the temperatures selected as the boiling points of the paraffin, aromatic and naphthene present in similar boiling point temperatures of the converted distillation cuts.

A wide divergence between the values of paraffins and aromatics is shown by table 26. An oil containing a mixture of the three hydrocarbons would show an index of refraction value somewhere between the values of the paraffins and aromatics. For example a mixture of paraffins, naphthenes and aromatics would give an index value depending upon the percentage of each type present in the oil. Now, if the mixture is nitrated the index of refraction value of the remainder of the liquid should show a value more clearly illustrative of its paraffin-naphthenic nature. The five examples taken from the data on the converted oils illustrates this. Table 27 shows this phenomenon:

The index value in each case is materially lowered after removal of the aromatics. There remains an oil whose boiling point range and index of refraction are known and which reacts chemically similar to either paraffins or naphthenes. The index of the oil corresponds closely to the values of naphthene oils at those temperatures as given in Engler-Höfer's "Das Erdöl." The latter reference gives for naphthenes boiling between 175 deg. to 201 deg. C., the value 1.44009. Our value for the fraction 175 deg. to 200 deg. C. is 1.44463, a fairly close approximation to the value of pure naphthenes. On these residues no bloom or paraffin separation was shown on cooling below zero deg. C., and this, in conjunction with the other physical and chemical tests, was taken as evidence of their naphthene content.

TABLE 27.

The index of refraction of the distillation cuts before and after nitration.

Oil Number	Distillation cut Deg. C.	Index of Refraction Before Nitration	Index of Refraction After Nitration
2	175 to 200	1.45671	1.44463
3	200 to 225	1.45471	1.44781
4	225 to 250	1.45111	1.44700
5	250 to 275	1.44891	1.44791
6	275 to 300	1.45121	1.44991

In the same manner the indices in table 23 taken after nitration of the converted oils are all uniformly lower than the indices before nitration as shown in table 10. It will be noticed, however, in table 23 that there is a general tendency toward lower indices of refraction values with increase of the boiling point fractions of the oils from 175 deg. to 300 deg. C. This is significant since the specific gravity values of the same cuts as shown in table 24 show a uniform decrease with increase of boiling point of the fractions as we go from oil number 2 to oil 6. In other words fraction from 275 deg. to 300 deg. C. of oil 6 shows a lower specific gravity than fraction 175 deg. to 200 deg. C. of oil 2.

This apparent contradiction to usual experience with oils seems at first difficult of explanation but some light is thrown upon this phenomenon if the amount of conversion of each starting oil is taken into consideration. It must be remembered that the six starting oils are distillation cuts from the same crude naphthene base oil and each oil from number one to six is a higher boiling-point fraction. Of the six oils, the highest boiling ones were number 5 and 6 which gave the highest percentage of conversion to lower boiling-point hydrocarbons. This brings out the great importance of the starting oils in conversion toward products which are desired. The type of hydrocarbons present in the oil is of the greatest significance in all catalytic, thermal and pressure decomposition work. And, it is certain that there are many crude oils which do not lend themselves readily to yields of importance of low boiling-point hydrocarbons.

In other words greater conversion has taken place in the higher boiling-point constituents, leaving compounds present in the same distillation cut of different composition, lower specific gravity and index of refraction than at first. Furthermore, the fractions above this one considered have broken down in turn to give com-

[10] Rittman and Egloff, *Jour. Ind. Chem. Eng.*, 7, 481, 1915.

pounds in the lower boiling cuts which also affect the physical constants. This change may be thought to be taking place in all six oils but as the higher fractions are less stable to the action of aluminium chloride than the lower boiling fractions a relatively greater difference in the physical properties would be manifested and our comparison is inverse to the usual experience in thermal and pressure decomposition of oils which although not strictly comparable, yet may be used as a means of analogy.

F. THE EFFECT OF ALUMINIUM CHLORIDE ON THE FORMATION OF GASOLINE FROM THE SIX FRACTIONS OF A NAPHTHENE BASE OIL, IN THE RECOVERED OIL

The effect of aluminium chloride upon gasoline formation in the recovered oil indicates a minimum in the fraction number two of 23.5 per cent and a maximum yield in fraction five of 47.3 per cent. A minimum is also shown in fraction six of 44.5 per cent of gasoline in the recovered oil. The oil distilling below 150 deg. C. has been taken as the gasoline cut. The analytical results are shown in Fig. 2. The specific gravity and the refractive index of these gasoline cuts, in particular that part boiling up to 95 deg. C., show a very high percentage of paraffins. The oils number 4 and 6 yield practically pure hexane and heptane.

G. THE EFFECT OF ALUMINIUM CHLORIDE ON THE FORMATION OF GASOLINE AND THE SPECIFIC GRAVITY OF THE GASOLINE FROM THE SIX FRACTIONS, ON BASIS OF OIL USED FOR PRODUCTION

The important point in gasoline formation is the question of how many gallons of gasoline can be produced from 100 gal. of starting oil. The two factors entering in the percentage of gasoline on the basis of oil used for production are the percentage of recovered oil after aluminium chloride treatment and the percentage of gasoline present in the recovered oil after treatment.

In this series of experiments the highest boiling point fraction number six, gave the greatest amount of decomposition of the starting oil for the production of gasoline upon basis of oil used for production, the percentage being 32.1, that is, the formation of 32 1/10 gal. of gasoline from every 100 gal. used. The lowest yield was 18.4 per cent from fraction two. From fraction two to six increasing amounts of gasoline were formed with the maximum in fraction six. In Fig. 3 the results are given in graphical form.

The physical constant specific gravity gives some indication as to the value of a gasoline, although it seems to the authors that in the past too much emphasis has been placed upon this constant as a criterion by which to judge the value of an oil as a motor fuel. Happily, for the modern cracking processes, most of which furnish some percentage of aromatics, the tendency is to lay less stress on the specific gravity of gasoline. All the data upon the conversion of heavier hydrocarbons to lighter boiling-point hydrocarbons from thermal and pressure decomposition or by the action of catalysts or chemical reagent seem to show the formation not alone of aliphatic hydrocarbons but also aromatic. As the specific gravity of the aromatic compounds is much higher than that of the aliphatic hydrocarbons, naturally gasoline formed by the above methods of preparation must be higher in specific gravity than gasoline derived by simple distillation of a crude oil at atmospheric pressure.

However, the mixture of aliphatic and aromatic hydrocarbons does not lessen the value of the oil as a motor fuel although the specific gravity of a gasoline derived from a converted oil is greater than that of a gasoline derived by simple distillation from a crude oil. The specific gravity of the gasoline cuts from the converted six fractions ranged from 0.726 to 0.801. Fraction six gave the lowest specific gravity and refractive index with the highest yield of gasoline of the six fractions. Fraction six was the highest boiling point oil of the six fractions having a distillation value boiling point mainly above 300 deg. C., which would indicate that in this type of oil the higher boiling-point oils lend themselves more readily to decomposition than lower boiling-point compounds.

H. THE FORMATION OF BENZENE, TOLUENE AND XYLENE FROM THE ACTION OF ALUMINIUM CHLORIDE ON THE SIX FRACTIONS

The formation of benzene occurred in fraction one and two only. The method of testing for benzene was by the simple one of addition of a sulphuric-nitric acid mixture and nitrating to mononitrobenzene, and determining its physical constants. No test for benzene was found for the cuts derived from fractions three to six inclusive. It is apparent that under the conditions of the experiment benzene was not formed in four fractions; this could only be due to the toluene and xylene which were formed not being in the sphere of the reaction a sufficiently long time, for it is well known that aluminium chloride and toluene or xylene will react so as to form not alone benzene but higher methyl derivatives of benzene. The reaction being a strictly reversible one.

$$C_6H_6 \longleftrightarrow C_6H_5CH_3 \longleftrightarrow C_6H_4\begin{matrix}/CH_3\\ \backslash CH_3\end{matrix}$$

The formation of toluene was found to be at a maximum in fraction one which fraction had the lowest boiling-point hydrocarbons of all the fractions. The minimum formation of toluene was derived from fraction six. The toluene present in the fractions was identified as the mononitrotoluene with its physical constants.

The maximum formation of xylene was obtained in fraction one, 9.8 per cent being formed, with decreasing percentage from fraction one to six. The high percentage in fraction one would indicate that this fraction was particularly adapted for the formation of aromatics as maximum yields were found in this fraction. Fraction one boiled mainly between the temperature of 150 deg. to 200 deg. C., containing naphthenes with aliphatic side chains which decomposed readily to form aromatic of the benzene series, and also hydrocarbons of much higher molecular weight than the starting oil. The total aromatic formation of benzene, toluene and

TABLE 28.

Temperature of lowest boiling constituent in the original fraction in degrees Centigrade....	150	175	200	225	250	275
Fraction No.	1	2	3	4	5	6
Per cent of the total aromatics benzene, toluene and xylene on the basis of recovered oil	13.74	10.59	6.70	5.91	5.31	2.26

xylene was 13.74 per cent in fraction one, which was the maximum formation. The percent of total aromatics decreased to a minimum of 2.26 in fraction six. do the low boiling fractions, but go more toward the aliphatic low-boiling hydrocarbons, low specific and re- The higher boiling-point fractions do not form aromatic hydrocarbons of the benzene series so readily as fractive index under the conditions of the experiments.

Table 28 gives the total percent of the aromatics benzene, toluene and xylene in the recovered oil.

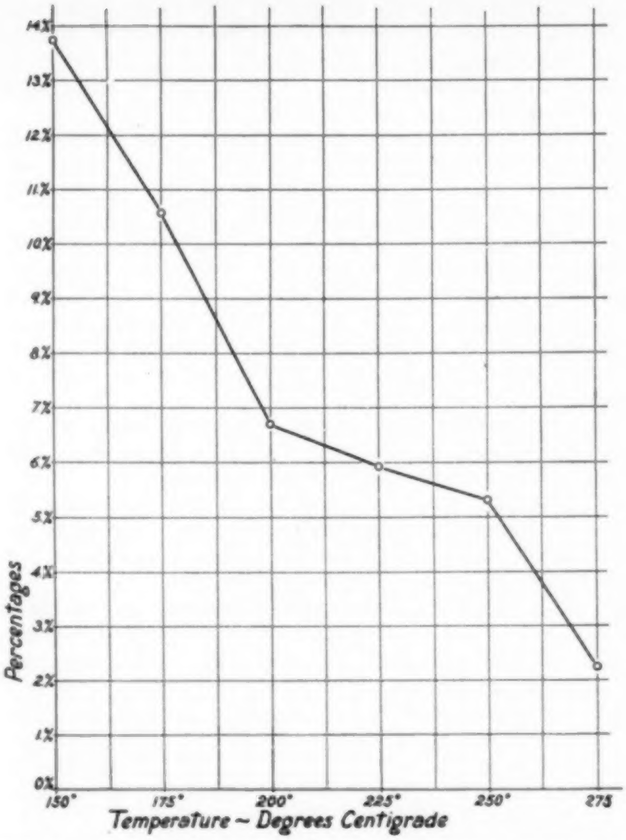


FIG. 7.—THE TOTAL PER CENT OF AROMATICS, BENZENE, TOLUENE AND XYLENE ON BASIS OF RECOVERED OIL

A decrease is to be noted in the total aromatic formation in the recovered oil as the fractions increase from one to six. The data is expressed in Fig. 7.

I. THE FORMATION OF BENZENE, TOLUENE AND XYLENE FROM THE ACTION OF ALUMINIUM CHLORIDE ON SIX FRACTIONS OF A NAPHTHENE BASE OIL, ON BASIS OF OIL USED FOR PRODUCTION

The formation of benzene on the basis of original oil used was found to be at a maximum in oil number two of 1.11 per cent. The toluene and xylene both gave a maximum in fraction one of 2.35 per cent for toluene and 7.8 for xylene. The toluene formation decreased from fraction one to three and increased in fraction four to 1.94 per cent, when another decrease occurred in its formation in fraction five and six. The formation of xylene decreased consistently as the fractions increased from lower to higher boiling constituents. The maximum formation of xylene was in fraction one of 7.8 per cent and the minimum formation of 0.88 in fraction six.

TABLE 29.

Temperature of lowest boiling constituent in the original fraction in degrees Centigrade....	150	175	200	225	250	275
Fraction No.	1	2	3	4	5	6
Per cent of the total aromatics, benzene, toluene and xylene on the basis of oil used for production	10.93	8.29	5.16	3.95	2.59	1.62

The maximum formation of combined aromatics on basis of oil used was obtained in fraction one, giving a percentage of 10.93. Table 29 gives the total aromatic hydrocarbon formation of benzene, toluene and xylene on the basis of oil used for production.

Fig. 5 gives in graphical form the data of benzene, toluene and xylene formation on basis of oil used.

J. THE SPECIFIC GRAVITY OF THE BENZENE, TOLUENE AND XYLENE CUTS RESULTING FROM THE CONVERSION OF THE SIX OILS

The physical constant of specific gravity is an excellent value for determining the per cent of benzene, toluene and xylene present in a cut when the oil is fractionated by means of a Hempel or Glinsky or other efficient distilling head.

The specific gravity of the benzene cut in fraction two gave a maximum of 0.771. In fractions three to six inclusive no benzene was formed, the cuts were mainly aliphatic hydrocarbons. From previous experimental work the specific gravity of the aliphatic hydrocarbons was found to average 0.720, while the specific gravity of the benzene has been taken as 0.880 at 15.5 deg. C. By simple calculation the amount of benzene present in the cut can be determined. Moreover each cut of the six fractions had been nitrated and the benzene present determined as nitrobenzene.

In the toluene cut of 95 deg. to 120 deg. C. the maximum in the specific gravity value was found to be in fraction two and minima in one and six. Similar to the method for calculating the percentage of benzene present in the cut, toluene may likewise be determined, for the average specific gravity of the toluene cut has been found to be 0.773 for the aliphatic hydrocarbons present. The value for pure toluene has been taken as 0.872 at 15.5 deg. C. Furthermore the toluene was experimentally determined as mononitrotoluene.

The maximum specific gravity of the xylene cut was found to be in number two, amounting to 0.814. The assumed specific gravity of the xylene cut for the aliphatic hydrocarbons present was calculated from specific gravity tables of the paraffin and olefin seried hydrocarbons present in the cut from 120 deg. to 150 deg. C. and the average was found to be 0.760. The specific gravity of the xylenes averaged 0.870.

The purity of the benzene, toluene and xylenes in the cuts can be determined from a knowledge of the specific gravity of the cuts. It is to be noted that the specific gravity of the benzene, toluene and xylene cuts reach a maximum in fraction two.

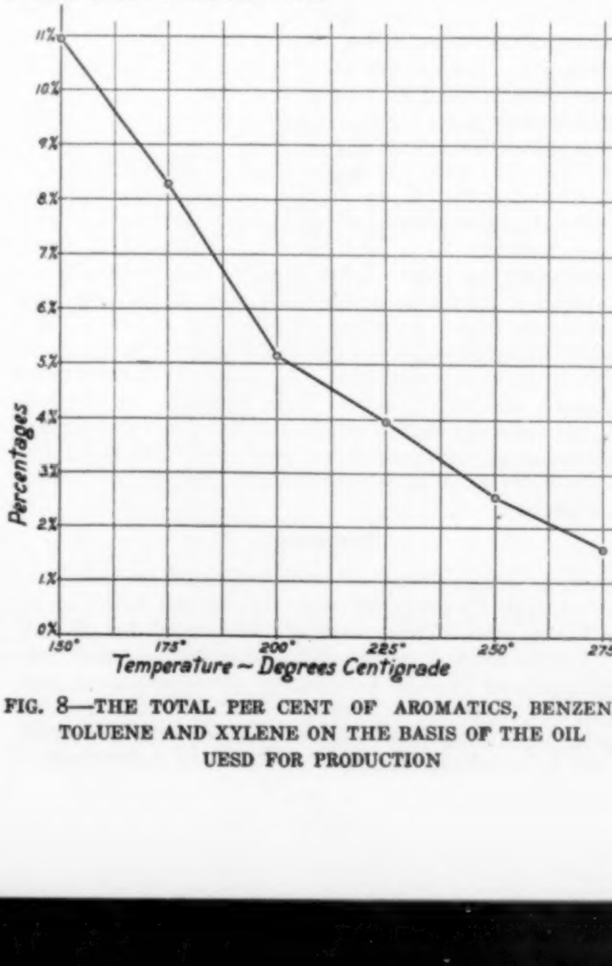


FIG. 8—THE TOTAL PER CENT OF AROMATICS, BENZENE, TOLUENE AND XYLENE ON THE BASIS OF THE OIL UESD FOR PRODUCTION

K. THE PERCENTAGE OF OLEFINS IN THE DISTILLATION CUTS AFTER CONVERSION OF THE SIX OILS

The percentage of olefins present in the cuts 95 deg., 95 deg. to 120 deg., and 120 deg. to 150 deg. C. was found to be practically zero. The gasoline cut to 150 deg. C. gave no olefins, was water-white and gave slight aromatic odor. In the distillation cuts above 150 deg. C. varying percentages of unsaturation were found to be present in the six oils, ranging from 1.6 to 10 per cent. The analytical results are given in table 20.

L. THE PERCENTAGE NITRATED IN THE DISTILLATION CUTS AFTER CONVERSION OF THE SIX OILS

According to the nitration values in table 21 the maximum values occurred in the xylene fraction of the cut of 120 deg. to 150 deg. C. of the six converted oils. This indicates the ready formation of xylene in comparison with higher or lower aliphatic derivatives of benzene. The tri-methyl benzene cut of 150 deg. to 200 deg. C. gave also high nitration percentage in the cuts. No indication could be gleaned as to the formation of naphthalene or anthracene from sulphonation, nitration, distillation, specific gravity, or refractive index tests upon the distillation cuts, although one would expect some formation from the polycyclic naphthenes present in the oil. There is a strong probability, however, of the formation of polycyclic aromatic hydrocarbons under suitable conditions of aluminium chloride treatment.

M. THE COMPARISON OF THE PERCENTAGE UNSATURATED, PERCENTAGE NITRATED AND PERCENTAGE UNATTACKED IN THE DISTILLATION CUTS OF THE ORIGINAL OILS AND THE DISTILLATION CUTS OF THE CONVERTED OILS

The gasoline fractions of the converted oils were with one exception free from olefins. A comparison of the individual distillation cuts on oils 1, 2, 3 and 4 shows a marked decrease in percent olefins after conversion. Oil No. 5 is exceptional in showing an increase in unsaturation of the distillation cuts yielding olefin formation even in the gasoline cut. For the entire converted oils the combined percentage unsaturation is higher than on the starting oils. The higher boiling fractions show rather marked stability toward the acid reagents and consist of naphthene hydrocarbons.

The percentage of the six oils nitrated in the distillation cuts after conversion is lower in all cases except one. This exception is noted in distillation cut of 175 deg. C. to 200 deg. C. in oil No. 1. The percentage decrease of nitratable hydrocarbons after conversion ranges between 73 to 454 per cent. This is in direct accord with the values found for the percentage of unsaturated compounds present in the distillation cuts after conversion. In other words, the action of aluminium chloride upon a naphthene base oil forms more stable hydrocarbons toward the reagents concentrated sulphuric and nitric acid. This property of the aluminium chloride should produce from high-boiling hydrocarbons of the naphthene base oil, lubricating oils of peculiar excellence, consisting mainly of stable naphthenes.

Summary

1. A naphthene base oil was subjected to fractionation of approximately 28 per cent of the total in six distillation cuts. These were distilled in 25 deg. C. cuts and their physical constants determined. They were then analyzed for the percentage of unsaturated, percentage of nitratable hydrocarbons, and the specific gravity and refractive index of the hydrocarbons unattacked by sulphuric and nitric acid were determined.

2. The six oils after treatment with aluminium chloride gave from 24.3 to 60.2 per cent yield of hydrocarbons boiling below the lowest boiling point constituent of the starting oil. The maximum conversion was in the highest boiling point oil.

3. The percentage of oil recovered after aluminium chloride treatment ranged between 60 and 79.3 per cent, the balance of the oil going to gas, carbon and losses due to neutralizing, washing and drying.

4. The specific gravity and the refractive index of the recovered oil was in each case lower than the starting oil, the greatest change taking place in the highest boiling fraction. This oil before treatment gave a specific gravity of 0.849; after conversion 0.774. A similar drop is to be noted in the refractive index of the oil.

5. The specific gravity and refractive index of the distillation cuts of the converted oils decrease as the boiling points of the starting oils increase.

6. The percentage of gasoline in the recovered oil ranged between 23.5 and 47.3 per cent. The gasoline formed was water-white, faintly aromatic and contained practically no unsaturated hydrocarbons.

7. The maximum percentage of gasoline on the basis of 100 gal. of oil used was found in the highest boiling point oil used and gave 32.1 per cent. The formation of gasoline from the six oils ranged between 18.4 and 32.1 per cent on basis of oil used for production. The highest percentage of gasoline converted from the highest boiling point starting oil gave the lowest specific gravity of 0.726. The specific gravity of the other gasoline cuts ranged between 0.726 and 0.801.

8. The formation of toluene and xylene reached a maximum in the recovered oil from the lowest boiling point starting oil, while benzene reached a maximum in the second lowest boiling point starting oil. These maxima were as follows on the basis of oil used for production; for benzene 1.11, for toluene 2.35 and xylene 7.80 per cent.

9. The percentage of unsaturated hydrocarbons in the oils before treatment was usually higher for the same distillation cut than in the converted oils. The maximum unsaturation in any distillation cut of the starting oils was 8.3 per cent while 10 per cent was the maximum in any distillation cut after conversion.

10. The percentage of nitratable hydrocarbons in the distillation cuts after conversion by aluminium chloride decreases as the boiling points of the starting oils increase. The percentage nitratable in the distillation cuts gave values ranging between zero and 43.6 per cent. These values were lower than any similar distillation cut before conversion. The high percentages of the nitratable hydrocarbons in the original oils is impressive, the distillation cut between 150 deg. and 175 deg. C. giving a value of 54.9 per cent.

11. The percentage of the stable hydrocarbons remaining after sulphonation and nitration in every case was greater in the converted oil.

Department of Inorganic Chemistry,
Columbia University, New York City.

Fuel Oil Appliances.—The W. S. Rockwell Company, 50 Church Street, New York City, has recently issued an attractive catalog on fuel oil appliances. A general discussion of oil burners is given together with descriptions of the various types of burners, pumps, and other accessory apparatus manufactured by this company. Blowers, tanks, strainers, valves, gauges, steam separators, and steam blowers, are also described. The catalog should prove of value to those interested in fuel oil furnaces and in the storage and handling of fuel oil.

Aluminium Castings and Forgings*

BY P. E. MCKINNEY

In the manufacture of light castings the following properties might be cited as mose desirable:

(a) Low specific gravity.

(b) A fair amount of strength and freedom from brittleness.

(c) Good machining properties.

(d) The maximum resistance to corrosion.

(e) Good casting qualities and freedom from hot shortness.

It is a well-known fact that pure aluminium is entirely too soft to produce satisfactory castings for most purposes and it is the universal practice to stiffen up the alloy with some hardening element.

Probably the most widely used hardener for aluminium is copper, which is used at the rate of about 8 per cent of copper to 92 per cent of aluminium. Zinc and tin are also frequently used as hardeners.

The use of these hardeners is attended with some well-recognized objections. In the first place, the addition of from 8 per cent to 10 per cent of hardener partially defeats the purpose of using aluminium in that the specific gravity is materially increased. The hardened metal while fairly strong has a strong tendency to brittleness and the alloys are in most cases less resistant to corrosion than either of the component metals. Hot shortness in the case of intricate castings is another feature attendant to the use of these hardeners.

In the Ninth Annual Report of the Alloys Research Committee Dr. W. Rosenhain and Mr. F. C. A. H. Lantsberry have published some very interesting data on the influence of manganese on aluminium alloys, which demonstrate beyond a doubt that these combinations have great promise in the production of light alloys. Various combinations containing manganese with or without copper and with a minimum aluminium content of 95 per cent have been used in actual foundry practices for the past two years with the most gratifying results. The use of manganese in relatively small quantities hardens and strengthens the alloy without destroying its ductility as is the case with copper or zinc. The machining properties are excellent and the comparatively small amount of hardener used makes possible a specific gravity in the finished alloy from 0.35 to 0.40 less than that of the ordinary No. 8 alloy. When properly made these alloys are practically free from hot shortness and the most intricate castings can be produced with comparative ease.

The statement has frequently been made that for the successful production of good aluminium alloys it is necessary to have available special melting furnaces and devices for handling the metal. This has not been found to be the case in handling the alloys of aluminium containing manganese which can be melted in natural draft pit furnaces, provided ordinary precautions are used in melting and fluxing the metal. The most satisfactory method of introducing the hardening elements is first, by alloying them with a small amount of aluminium, making a rich hardener of definite proportions and compartively low melting point.

The most dangerous impurities encountered in aluminium alloys are carbon, silicon and iron, hence, the greatest precaution should be taken to prevent introduction of these impurities either in the metal used or through the medium of crucibles and tools. With this in view carbonless manganese produced by the thermit process has been used exclusively for this purpose. This is alloyed with copper when aluminium-copper-manganese is being made by melting 60 per cent copper and introducing 40 per cent of manganese in small pieces, heating until the two metals have combined, which is seen by the smooth condition of the surface of the metal. This alloy can then be diluted with an equal weight of aluminium to reduce the melting point although it is perfectly feasible to use copper-manganese direct. In making the alloy of manganese without copper 80 per cent aluminium is first melted, brought to a bright cherry red and 20 per cent manganese added in very small pieces. The alloy should be poured as soon as the manganese is all dissolved.

In melting aluminium alloys clay crucibles or clay-lined crucibles are preferable. No charcoal or carbonaceous covering is used on the metal as carbon combines with this alloy forming a very brittle compound. Gates and sprues from castings must be carefully cleaned and freed from sand as practically all the sand introduced into the pot is reduced to silicon which materially weakens the alloy. In cases where there is danger of introducing sand into the crucible it has been found very beneficial to introduce a powdered flux which is made by melting together 60 per cent of potassium chloride and 40 per cent of kryolite and powdering the mixture. This flux tends to dissolve the silica and keeps it from combining with the aluminium.

In preparing the alloy for casting purposes an empty crucible is set in the furnace and heated to a bright red heat. The requisite amount of hardening alloy is added and melted as quickly as possible. As soon as the hardener is melted the draft is cut down by opening the cover of the furnace and aluminium is added in small increments as fast as it will melt, timing the additions so as to keep the temperature of the mixture at not more than a faint red heat. The crucible is drawn from the furnace just before the last of the aluminium is melted in order to prevent the metal becoming overheated. This is a very important point as overheated aluminium will absorb silica from the walls of the crucible at a very rapid rate and it has been found that once overheated this aluminium is practically worthless for future use. Just before pouring there is added to contents of crucible about 1/4 oz. zinc chloride and the metal is thoroughly stirred with a clay-covered skimmer. This zinc salt tends to reduce the oxides and dross in the metal and puts it in ideal condition for casting purposes. Alloys of aluminium containing manganese have a slightly greater shrinkage than those containing copper alone, and due allowance must be made by using simple risers and chill plates on intricate castings.

The following are results of tensile tests of coupons from sand cast aluminium castings taken at random from recent heats:

Composition: Manganese, 1.50 per cent, copper, 2.00 per cent; aluminium, 96.00 per cent.

Tensile Strength, Lb. Per Sq. In.	Elongation Per Cent in 2 In.
22,000	15.0
22,000	14.0
21,000	8.0
19,000	9.5
19,000	14.7
19,000	14.0
21,000	13.0
22,000	12.0
24,000	10.0
19,000	12.0
18,000	13.0

The elastic ratio of this alloy as determined by the drop of the beam of the testing machine will average about 60 per cent of ultimate strength.

The fracture of test specimens is silky and shows considerable toughness instead of being granular and brittle as is the case with many aluminium alloys. Castings are practically free from hot shortness and it has

*A paper read at the Cleveland meeting of the American Institute of Metals.

been found to be perfectly feasible to make castings with very thin webs without any trouble due to this cause. Alloys of aluminium containing manganese have found to work very freely either by cold roling or hot forging and many intricate shaped drop forgings have been produced by its use.

In preparing the alloy for forging purposes the same precautions are observed in melting and pouring the ingots as in the case of sand castings. The same type of ingot molds as are used for bronze forging ingots are suitable for aluminium. The ingot molds are heated to about 500 deg. Fahr. and given a thin coating of orange shellac to produce a clean skin. The metal should be carefully skimmed and poured very quickly in order to prevent cold shots due to the low temperature at which it must be poured.

In making drop forgings from aluminium a little preliminary forging is very desirable. The ingot can be cut or cropped to the desired lengths and forged to approximate shape at a temperature of from 1150 deg. Fahr. to 1400 deg. Fahr., after which they can be finished in the dies. These alloys flow with ease during forging and dies have been found to fill very nicely in all cases. Forging dies of the same type as are used for tobin bronze forgings are perfectly satisfactory for aluminium work.

The stiffness and strength of the forged material can be controlled by varying the finishing temperature. Considerable stiffness and elasticity can be imparted to the forgings by two or three blows of the forging dies at about 500 deg. Fahr.

The following are typical physical properties obtained on bars of this alloy forged to 1 in. square and turned to standard size tensile specimens.

Soft alloy containing:

Manganese 1.00 per cent, copper 2.00 per cent, aluminium, 96.50 per cent.

	Tensile Strength	Yield Point	Elongation	Reduction
Cold finished	27,750	27,750	12.00	47.00
Hot finished	21,083	12,223	26.7	48.7
Intermediate	25,617	22,918	17.4	52.00

Hard alloy containing:

Manganese 2.00 per cent, copper 3.00 per cent, aluminium, 94.50 per cent.

	Tensile Strength	Yield Point	Elongation	Reduction
Cold finished........	31,930	30,000	9.75	35.3
Cold finished........	34,123	33,000	4.00	11.25
Cold finished........	30,405	30,000	11.25	30.78
Hot finished.........	27,450	15,000	21.95	56.0
Intermediate	28,670	22,000	21.00	50.4

Sections cut from thin drop forgings which were cold finished have shown tensile strength as high as 40,000 lb. per square inch. The forged material machines very nicely and shows a fine silky fracture when broken. The increased density of the metal produced by forging makes it a great deal more resistant to sea water corrosion than the cast alloy. Several drop forgings of these alloys are now undergoing service tests on ships at sea to determine their resistance to corrosion and reports thus far received are very promising.

Considering the low specific gravity of these alloys together with the strength and ductility obtainable the material compares very favorably with the heavier bronze and brass forging materials for many purposes.

U. S. Naval Gun Factory,
Washington, D. C.

Canadian Nickel Refinery.—The new electrolytic nickel refining plant at Niagara Falls, Ontario, was expected to be finished Sept. 1. The province of Ontario expects to refine its nickel at home when the plant is finished.

Alloys to Withstand Internal Air Pressure*

BY S. D. SLEETH

At the request of Mr. Clamer I have attempted to set forth what we might term a few observations upon the subject of "alloys to withstand internal air pressure." Brass and bronzes have as a rule been recognized as metals adapted especially for this purpose, and this paper will, therefore, be confined to the use of such alloys. Density and strength are the two qualities that go to make up a metal suitable for the retention of air or other gases under pressure and while strength may be secured through proper design, density is that elusive will-o'-the-wisp which we chase for a while in one direction and think we have captured, only to find that it has eluded us and we must look for it elsewhere.

This leads us then to the conclusion that there can be no hard and fast rule whereby this desirable quality of density can always be obtained, probably because of the fact that there are so many variables that enter into the process and that they cannot always be under our control. To enumerate some of these variables, we have the design of the article to be cast, the design of the pattern with reference to its position in the flask, composition of the alloy, the treatment of the metal in the furnaces, and the temperature of the metal when being poured. Each item in this list is worthy of extended discussion, but time will not permit of more than a cursory glance at each subject.

We shall begin with the design of the article to be cast. This has a very important bearing upon the ultimate success of the casting. The designer should bear in mind the desirability of having all cross-sections of approximately equal thickness in order to prevent draws at heavy portions. If this is not possible, access to all large sections should be allowed for the use of chills to prevent such draws. If the cored cavities are large the cores will, themselves, act as chills. Fillets should be as small as possible in order that excessive masses of metal shall not be concentrated all at one point.

In laying out patterns, the patternmaker must be governed by several things. He must know what chills are to be used so that large chilled surfaces may be placed in a vertical position in order to prevent the metal kicking off these surfaces. He must know what parts are to be clean, such as valve seats, etc., and to what parts loose sand may be allowed to flow if any be found in the mould. Such unimportant parts should be placed high in the cope and the loose sand will flow to them on top of the metal. A clean mould, however, is absolutely essential to good tight castings. An exceptionally clean casting may be obtained by gating it from another casting which will itself take all the dirt.

On the use of chills, I might state as an almost universal law: Use chills on all enlarged sections in close proximity to smaller sections and connected thereto. If the sections are exceptionally large, use a sinking head on top of the large sections. Gate your moulds with a heavy upright pouring gate as near to the pattern as possible. The gate leading from the pouring gate to the pattern should be made large at the pouring gate and then reduced sharply into the pattern. If it is large where it joins the pattern, in all probability it will show a draw in the casting at the gate. As a rule, it is better to gate in a light part of the casting than in a heavy portion. If a sinking head be used it should be placed on the heavy part.

As regards the alloy to be used, the following com-

*A paper presented at the Cleveland meeting of the American Institute of Metals on Sept. 13, 1916.

positions have been tried and found satisfactory for the purpose intended:

Metals	No. 1 Alloy	No. 2 Alloy	No. 3 Alloy
Copper	72.50%	82.00%	83.00%
Tin	1.75%	7.50%	11.50%
Zinc	19.25%	4.75%	4.00%
Lead	6.50%	5.75%	1.50%
Total	100.00%	100.00%	100.00%

No. 1 alloy is used for ordinary castings, such as cocks, pistons, bushings, etc. This alloy is easily machined, but is not intended for use with very high pressures.

No. 2 and No. 3 alloys are intended for use with high pressures and are harder to machine in proportion.

As might be expected, the treatment of the metal in the furnaces is of vital importance. If proper allowance for oxidation of zinc, etc., is not made the alloy intended will not be produced. Furthermore, the metal must be taken from the furnace as soon as it reaches the proper heat, for if allowed to soak in the furnace it will take up gases and the castings made from it may be porous. In certain packing ring mixtures we consider this item so important that we use an alarm clock to insure the metal being poured off at exactly the proper moment.

The temperature at which the metal should be poured into the moulds is important, and no doubt many castings are lost due to carelessness in this matter. If poured too cold it is almost impossible to obtain solid castings, especially at the gate. On the other hand, if poured too hot, the castings may be porous throughout. Great care must be taken to see that no aluminium gets into the mixture, as very small percentage of it will cause the castings to leak. Antimony and iron will do the same, but not to so great an extent. Aluminium has a very peculiar action on the metal. The castings will look solid and will not show a draw, but when put under pressure will leak all over. It is one of the most dangerous metals around the brass foundry. Antimony does not act as quickly as aluminium, but has about the same effect if used long enough in the mixture. You may start out with a small percentage and it seems to do no harm, but if used until it is mixed with all returned material, such as turnings, gates, etc., the castings will become porous.

In conclusion, let me say that solid castings of a density to withstand air pressure can be obtained only by the exercise of the greatest care from the design of the article to the pouring of the metal into the mould. Even then failures will sometimes happen and final success can be obtained only through experiment and the adaptation of the various methods to the article under consideration.

Westinghouse Air Brake Co.

The Determination of Sulfuric Anhydrid

BY EDWIN G. PIERCE

Some methods for cement analysis, worked out to secure the greatest possible accuracy, exceed the degree of precision required for routine and control work. The writer has pointed out[1] that the use of the reflux condenser in the Newberry, or "acid and alkali" lime determination is unnecessary and involves considerable loss of time.

In the determination of sulfuric anhydrid, specifications usually require that the precipitated barium sulfate, shall stand five hours before filtering, and this seems to be a well-chosen period. The following shorter method, however, will consistently give the same result, within a few hundredths, and allow the analyst to complete a routine cement analysis (excepting the magnesia) in four hours. It is equally applicable to the precipitation of barium sulfate in any other industrial analysis.

[1]Journal of Industrial and Engineering Chemistry, Vol. 7, No. 3, p. 258.

Preliminary Observations

Filtrates from barium sulfate separations, allowed to stand for varying periods, and stirred with a centrifugal motion, always showed some precipitate collecting in the center, indicating that the determination as ordinarily carried out with commercial papers is at best only approximately correct. Various papers and changes in the method were tried, but always some sulfate would appear in the filtrate. Next, the filtrate was collected in three portions, viz.: (*a*) the supernatant liquid, (*b*) the filtrate secured while bringing the precipitate upon the paper, and (*c*) the wash water. In nearly all cases less precipitate appeared in (*a*) than in (*b*) and (*c*), showing that precipitation was compelte, but the sulfate was carried through the paper mechanically.

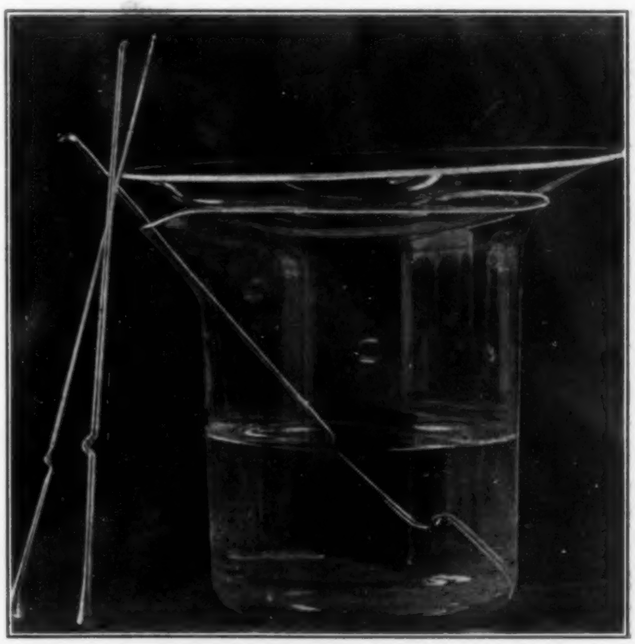
Theoretical Part

Zsigmondy states[2] that the crystalloid solubility of barium sulfate is too great to permit its preparation as a colloid, and according to the colloidal theory of P. P. von Weimarn[3], particles of colloidal solutions are all crystalline, and the size of the crystals depends upon concentration, pressure, and temperature conditions.

Ostwald[4] points out that small crystals are more soluble than large ones, hence, when both are present, there will be a condition of supersaturation for larger crystals, causing them to grow; and of hypersaturation for small crystals, causing them to dissolve—high temperatures also increase this solubility.

Lehman, in explaining the process of crystal growth, brings out the following points: When a precipitant is added to a solution at a given point, causing crystals to form, the solution becomes impoverished at that point, tending to the formation of smaller crystals. The growth of crystals is aided by diffusion currents in the liquid by which fresh material is brought in contact with the nucleus. Secondary and tertiary lines of

[2]Colloids and the ultramicroscope.
[3]Arbeiten Weimarn.
[4]Lehrbuch der allgemeinen Chemie, 2nd Ed., p. 757.



BEAKER WITH BOILING TUBES

growth shoot off from the parent stems, thus exposing greater surface to the diffusion currents, and causing skeletal outlines to fill out. Growth is retarded by the presence in the solution of layers of different temperatures, which affect pressures and solubilities.

From the above considerations it is evident that to suppress the formation of small, and assist the formation of large crystals from the outset, and to foster the growth of these large crystals at the expense of the small ones, will add to the completeness of the barium sulfate separation.

Description of Short Method

To provide an even distribution of heat throughout the solution, prevent "bumping," diffuse the precipitant rapidly, and constantly reduce the volume of the solution; boiling tubes are used as shown in the illustration. These consist of a capillary tube attached to a stem of convenient length, and give a steady flow of bubbles from the bottom which prevents superheating, and boiling may be continued without direct attention as long as desired.

The boiling barium chloride solution is added very slowly, allowing rapid diffusion, and boiling is continued till the barium sulfate settles to the bottom. The boiling tube is then removed with a quick motion while boiling continues so that no liquid will be drawn into the capillary, and the beaker placed on a sand-bath or hot-plate kept just below the boiling point, and allowed to stand about two hours. The solution is then rapidly cooled and is ready to filter.

From theoretical considerations already mentioned it is evident that a slow paper is preferable, as there will be less suction and less sulfate drawn through while bringing the precipitate upon the paper. The larger crystals and skeletal forms will clog the pores and hold back the smaller crystals, but some particles of small size pass through before this takes place, as shown by an examination of the filtrate.

For the same reason it is best in washing not to disturb the matt of crystals first formed on the paper, but merely circle the top with the stream from the wash-bottle, since, by more violent washing, there is a greater loss of small particles.

In bringing the precipitate upon the paper there can be no advantage in any extensive washing and swabbing of the beaker to remove last traces of barium sulfate, since each additional washing carries more small particles through the paper than will be removed from the beaker.

If the precipitation has been properly carried out and the barium sulfate settled out perfectly clear, it can be brought upon the paper and the beaker sufficiently rinsed in three applications of the wash-bottle, and with three additional washings of the paper the filtrate will show barely a trace of chlorides. The writer uses double papers requiring three to five minutes to drain. The precipitate secured in this way will ash perfectly white to constant weight at 925 deg. C. in twenty to thirty minutes.

If desired the analyst may easily work out a correction factor, but, with sufficient practice this should be unnecessary for routine work. Whatever period of standing is allowed the boiling tubes will be found a distinct advantage and can be used in other boiling operations.

For greater precision in the separation of barium sulfate, the excellent papers of P. P. von Weimarn[5] give valuable hints.

Table I gives a comparison of results.

Youngstown, Ohio.

TABLE I—DETERMINATIONS OF SULFURIC ANHYDRID

Sample	Boiling Tubes	Time of Standing in Hours	Residue from Supernatant Liquid	Residue from Washing Beaker	Residue in Wash-Water	Number of Washings	SO_3 in %
			Trace < 1 < 2 < 3 < 4 < 5				
1	Not used	36	Trace	2	1	5	1.46
	Not used	5	Trace	2	2	7	1.46
	Used	2¼	Trace	2	2	3	1.46
2	Not used	42	Trace	3	2	7	1.40
	Not used	5	Trace	1	1	7	1.43
	Used	2¼	Trace	2	1	4	1.42
3	Not used	36	1	3	2	5	1.48
	Not used	5	Trace	2	1	7	1.56
	Used	2¼	Trace	1	1	3	1.57
4	Not used	36	1	3	3	5	1.57
	Not used	5	Trace	1	1	7	1.61
	Used	2¼	Trace	2	1	3	1.60
5	Not used	36	Trace	3	2	7	1.42
	Not used	5	Trace	1	2	5	1.44
	Used	2	Trace	½	1	3	1.44

Synopsis of Recent Chemical and Metallurgical Literature

Fuel Economy in Great Britain.—A discussion of the necessity of practicing the strictest economy in the utilization of fuel, and some interesting data on the fuel situation in Great Britain were given in a paper by HENRY E. ARMSTRONG, presented at the recent meeting of the Society of Chemical Industry at Edinburgh and published in the July 31 issue of the *Journal* of the society.

The author states that the fuel situation is daily becoming more and more serious. Coal is very expensive, and there is almost an absolute shortage of liquid fuel for internal combustion engines, and the shortage of dyestuffs is partly due to the lack of raw material. It would be advantageous to carbonize far larger quantities in ovens or retorts, and the nuisances created by the emission of smoke and acid products must not be overlooked. The utilization of coal should be considered from the more comprehensive point of view, as the raw material from which both liquid fuel and the primary materials required by the dyestuff industry and other branches of organic chemical industry are derived—not forgetting the high explosives which are playing so dominant a part in the present war; also as the potential source of vast quantities of ammonia, invaluable as a cereal manure, as well as of not a little sulphur.

The author continues as follows: "It is certain that we have little moral right to use coal simply and directly as fuel; from this point of view, should we not memorialize government at once to foreshadow legislation prohibiting the use of raw coal, as a fuel, at no distant date? I am told that the use of raw coal was stopped in Germany at an early period of the war. . . . Soft coke is necessarily to be regarded as the solid fuel of the future; yet if such be the conclusion, a situation will soon be created that must not be overlooked. Obviously if gas and soft coke be the fuels of the future, the town gas industry, as at present conducted, will need complete reconstruction—the gas works will be called upon to produce both gas and soft coke and to serve as the primary source of fuel supply in its district; moreover, it will almost necessarily be run in conjunction with the supply of electricity. Already the Brighton Corporation have made arrangements for the installation of a coking plant alongside their electrical works, the gas to be used in firing the boilers of the latter; it will be but a small departure to obtain an act for-

[5]Grundzüge der Dispersoid Chemie.

bidding the use of raw coal in the district which will make the soft coke produced of special value to the town.

"In my Newcastle paper I referred to the production of soft coke as still problematic; I was not then aware what had been done to improve Mr. T. Elwell Parker's process, which gave a coke of unexceptionable quality though on far too small a scale to be practicable. In the interval, a gas fired fireclay oven has been devised in which coking can be effected on a satisfactory scale. I am informed that in Germany probably a dozen such plants are in operation which have been erected since the war began, and that the design of these is based upon information derived from the experiments made in this country. Similar plant will soon be in operation in this country near Barnsley, in the center of the South Yorkshire coal field; this will be run in conjunction with an electrical works and a tar distillery. Such being the case, it would seem that the experimental stage is past and that all that is required is independent study by competent authority of the plants referred to when they are in operation.

"But there are many problems connected with the economical use of coal which must be fully inquired into. It is essential that both the funds and the machinery for such inquiry should be provided without delay. The appointment of a central National Fuel Board to initiate and supervise all necessary inquiries would seem to be the first step that is called for, and I venture to think that no better way of obtaining funds can well be suggested than that I have already proposed —*i.e.*, a small tax on all coal raised in the country. I hope the society will be prepared to take action in the manner suggested."

The paper brought out considerable interesting discussion.

The president, Dr. Charles Carpenter, said that it was very difficult to foresee the universal use of gas or electric heating, and, in the intermediate stage, some form of solid fuel might be used. The breakdown in the coalite experiments had been very unfortunate in many respects. The fundamental idea of Mr. Parker was to carbonize the coal in small cells, and in itself was an admirable one—but when he had put it into practice he was handicapped by the fact that he had been brought up and trained as an iron founder and so naturally turned his thoughts to making his cells in iron.

Dr. E. F. Armstrong urged that there was still a great deal to be done by manufacturers in economizing coal. The best incentive to economy was an increase in price, and from that point of view the present increase —disastrous as it was to many—was a great incentive to economy in the future. The firm with which he was connected had made it a practice for many years to employ a highly skilled chemist entirely to look after their fuel and water supply, and that policy had been more than justified by results. It was a policy worthy of being imitated very largely in British industries, not so much chemical industries, but engineering industries in particular, and by many others of our great industries. He mentioned a case of one firm who had benefited greatly by the installation of a CO_2 recorder. It was only the largest firms who could afford to have an expert for themselves, but it might be possible for half a dozen firms in a neighborhood mutually to engage an expert to look after their fuel and water problems, by which he was sure great economy in utilization might be effected.

Mr. R. H. Clayton said that in Manchester quite recently they had obtained statistics as to what the losses due to smoke amounted to; they were so large that he thought he was quite justified in the view that the smoke problem was the most important of all fuel questions.

Mr. A. MacDonald asked how the ash in soft coke was to be got rid of. In Glasgow they had been deeply interested in clearing the smoke from the atmosphere, and one member of the Council was experimenting with a view to producing a coke which would be useful for house fires, but he had found that it contained an excessive amount of ash and had low heating power. The same trouble had been found in similar fuel prepared by a small works in London.

Mr. R. Maclaurin said that the fuel to which Mr. MacDonald had referred was made from cannel coal, hence the large percentage of ash. With a coking coal a smokeless fuel containing not more than 7 or 8 per cent of ash was readily obtained. The chief difficulty he had experienced in the experiments he was conducting at the Glasgow Corporation's Electricity Station, Port Dundas, was in getting a fuel that would not spark. The sparking was due to the coke dropping while red hot into water. By drying, or avoiding quenching the coke in water, a satisfactory smokeless fuel was obtained. In the low temperature carbonization of coal by his process very satisfactory yields of oil were being obtained. The oil was fairly fluid, and after separation of a resinous portion would be suitable, he thought, for lubricating purposes or for Diesel engines. The oil contained practically no benzene nor toluene, as was to be expected in a low temperature process. An unexpected result, however, was the almost entire absence of illuminants in the gas made. In some experiments the coal was carbonized by a current of hot water-gas, without any external heating, and he had found that the mixed gas given off from the coal in this way seldom contained more than 0.4 per cent of olefines; had the coal given off 4000 or 5000 cu. ft. of gas of 700 or 800 B.t.u., the olefines should have amounted to fully 4 per cent. In other low temperature processes he was convinced that considerable decomposition took place, giving rise to the illuminants present in such gas. The absence of illuminants in his process convinced him that smokeless fuel would be manufactured more economically in electricity stations than at gas works. His plant was in two parts. When working for power gas and smokeless fuel, air and steam were blown into one chamber where they burned the fuel added to ash, and the gas passed from this chamber into a second chamber, which was practically a large water sealed producer, 30 ft. high by about 8 ft. diameter. The current of hot gas completely carbonized the coal being added to this chamber. The smokeless fuel was drawn out at the bottom through a water seal. In this plant there was no difficulty in carbonizing uniformly 1 ton of coal per hour. The gas made in both chambers, after cooling and scrubbing, was available for gas engine running or boiler firing. When smokeless fuel was not desired the fuel could be burned to ash in both chambers, and gave practically the same yield of power gas as an ordinary producer, but the quantity and quality of the oil recovered were much enhanced.

Mr. J. G. Roberts said that in the pottery trade he did not think there was a plant in existence using gas firing which had been an unqualified success. The two biggest plants that he knew of had been abandoned. For pottery firing a long and intensely hot flame was needed, and good coal was required to get that flame. The regenerative system of heating had not been profitably applied to the heating of pottery and the expense of repairs became very great.

Mr. W. F. Reid said that he thought the prohibition of the use of solid fuel was quite impracticable at pres-

ent. Public opinion was not yet ripe for that. They must first try to educate public opinion to the great evils and probably the injury to health due to the consumption of coal. A great deal had been done in reducing the amount of smoke from coal. As a member of the Council of the Coal Smoke Prevention Association, he said that they were quite satisfied with the progress that had been made in London and other large cities—especially with regard to the elimination of fogs in London. The use of more gas had had some influence, but so also had the expression of public opinion and in a few cases the action taken by local authorities. Dr. Haldane had recently pronounced the opinion that the particles of carbon contained in smoke were distinctly beneficial to the lungs of those who breathed them, and he was now endeavoring to prove that it was beneficial to inhale particles of carbon to prevent tuberculosis. His own belief was that it was the tarry substances that were so injurious.

Mr. W. F. Cooper expressed the opinion that the trouble really was that there was no one in Parliament who really understood the subject.

Dr. J. T. Dunn said that some progress would be achieved if consumers as a body could be persuaded that it would pay them to buy coal on a calorific basis. Good coal was high in price, but with ordinary inferior coals, the price diminished very rapidly, so that it did not pay to sell the latter. That was the reason why those coals were not in many instances worked. Sale on a calorific basis would, he thought, enable colliery owners to work those at present unworked portions of the seams with greater prospects of getting some remunerative price. There were many advantages in low temperature carbonization processes, but it was not possible to have all the advantages at once. In the ordinary process of gasworks, a very small proportion of the nitrogen was recovered, but low temperature processes, where the solid fuel produced was burnt directly, as in domestic grates, recovered a smaller proportion still. If, however, the solid fuel was consumed in a low temperature gas producer, a greatly increased yield of ammonia could be obtained.

Mr. W. J. Rees agreed that the purchase or sale of coal on a calorific basis would be advantageous. He did not think it was the purchaser but the colliery proprietor who stood in the way in that connection. If such a scheme could be brought into operation successfully, it would be to the mutual benefit both of the colliery owner and the user of the coal.

The president remarked that the origin of Dr. Haldane's experiments was that he had found that miners as a class were particularly free from tuberculosis, and having regard to the dusty conditions in which they were working, he was led to believe it might be due to the coal dust. The fog question was more important still. The fog caused the rise in mortality, and the discomfort, and he thought that most of the troubles arising from the imperfect combustion of coal were not due to "smuts," but to the products of distillation.

Professor Armstrong in reply said that he wished to make it clear to this society that it had a mission which it could fulfill. There was now a golden opportunity for it to take up this subject and make it their own. They should be put in a position to approach Parliament on the subject and urge our views upon them. The whole subject must be dealth with from a practical point of view and proved by results. Great credit was due to a man like Mr. Elwell Parker for conceiving the idea and spending so much time in experiments on a subject of which he knew nothing—that was the type of man who started things in this country; but some concerted effort should now be made to work the problems out. They could be worked out in a very few years, he was sure. The original coalite process was a low temperature process conducted in such a way that the products were carried off immediately, and there was practically no benzine or toluene in the tar, but a good deal of carbolic acid of much higher quality than was produced in any other way. The real source of benzine in those processes was not the tar but the gas. The gas produced was very rich, and if stripped it gave a satisfactory amount of benzene, leaving gas of a high calorific value which needed dilution to be used for ordinary steam-raising purposes. He now felt highly confident that the work had been taken in hand in such a way that there was every prospect of good results being attained. His own view was that the gas industry ought to take the matter very seriously into consideration.

Influence of the War on British Tar Distillation Industry.—In a paper presented at the recent meeting of the Society of Chemical Industry in Edinburgh, W. H. Coleman gives some interesting data as to the present status of the British tar distillation industry. The biggest problem is the disposal of the pitch. The price of this product fell considerably after the war started due to the stoppage of exports. Most of the pitch exported was used in making briquets. Several proposals have been made for utilizing this pitch. One proposal was to mix a proportion of pitch with the coal charged into the gas retorts. It has also been proposed to render non-coking coal fit for coking by adding a proportion of pitch before charging into the ovens. No results on this have been published and it offers little hope since most coking coals lose their coking property when heated to about 400 deg. C. It is possible that low-temperature pitches, such as those obtained from the producer and the blast furnace tars, may be more suitable for this purpose than gas works tar, and coke oven tar. One field which offers considerable promise is the making of briquets. Very large quantities of slack coal are produced and if the slack were washed, the nuts being used for fuel direct and the finer briqueted a greater efficiency will result. Large quantities of coke breeze might also be usefully formed into briquets. Outlets for benzol and toluol have to be found when the demand for explosives ceases. The revival of the color industry will take some, but the balance could be used as motor fuel in admixture with alcohol. Creosote may have a bright future in Diesel type engines. On June 30, 1916, there were 356 tar distillation plants, a very rapid increase having taken place as in 1912 there were only 221. The author suggests the establishment of a central research laboratory, some of the questions to be solved being as follows: The cause of corrosion in tar stills. Is the present method of separating the fractions the best in view of the products required? An investigation of creosote oil and of the lesser known bodies in the distillates with a view to finding uses for them. An investigation of coal gas pitch to find means for rendering it less brittle when cold and raising its melting point, so as to render it, if possible, more suitable for replacing natural asphalt. The standardization of the methods of testing coal tar products. Meetings might also be held from time to time to discuss ways and means of preventing useless competition and conferences might take place with representatives of the gas making and coke oven industries to discuss questions of mutual interest. Many other suggestions might be made but the whole can sbe summed up by saying that the great need is organization and co-operation, so that advantage may be taken of all opportunities of improving the prospects of the industry.

Progress of Rare Earth Industry in England.—In a Society of Chemical Industry paper presented at the recent Edinburgh meeting, SIDNEY J. JOHNSTONE gives a review of progress in the British rare earth industry. The British industry has undergone several extreme changes during the past two years, varying from a serious shortage of most of the necessary raw materials at the outbreak of the war to a much better present position. England formerly imported practically all of her thorium nitrate used in making incandescent mantles from Germany. At the outbreak of the war these imports ceased and as little was obtainable from France, and practically none from the United States, investigations of sources of monazite sand were undertaken. The only known deposits of monazite sand of any commercial importance at present are those worked on the coast of Brazil and in Travancore, India,* the latter sand being of considerably greater value because of its higher content of thoria. For several years prior to 1914 the whole output of Travancore, amounting to 1300 tons per annum, and equivalent to 2300 tons of the best grade Brazilian sand, has gone to Germany for treatment. The concession for working the deposits was held by a British company, the London Cosmopolitan Mining Co., and the output was sold under contract to a German firm. At present the output is going to the United States and England. During the past year a considerable quantity of Travancore sand was sent to the United States for treatment and many incandescent mantle manufacturers in England have had to depend on supplies of thorium nitrate from this country. In addition to the company mentioned above, another company, called Thorium, Ltd., has recently obtained concessions to work a 150-acre deposit. This company ships its output to London and manufactures thorium nitrate there. Rights to work the Brazilian deposits are mostly held by German firms. Each Brazilian state has a separate export duty. The quantity exported has gradually decreased from 6462 metric tons in 1909 to 1437 metric tons in 1913. Later returns are not available.

The incandescent mantle manufacturers in England use thoria equivalent to about 650 tons of Travancore monazite sand per year. Unless the mantle industry is considerably extended, the important resources of monazite sand will go to other nations, as England is not able at present to use a normal year's output from Travancore. There are several industries using small amounts of thorium, the most important of which is the manufacture of filaments, of an alloy of tungsten and thorium, which was imported from Germany.

Pure cerium compounds, obtained by treating the residue after extracting thorium from monazite, suitable for use in the manufacture of incandescent gas mantles and optical glass, can be obtained in adequate quantity in England, a fair quantity being imported from the United States. Pyrophoric alloys come also from the United States. By an "order in council" dated February 23, 1916, the export of the oxide and salts of cerium, metallic cerium, and its alloys, except ferrocerium, was prohibited to all destinations. Ferrocerium wsa allowed to go to British Colonies.

Didymium salts, which are obtained from the same source as cerium, and are used for branding incandescent mantles, are imported from the United States.

Tantalum filaments are being made by one firm in England from tantalite. The zirconia which is used is imported from the United States. The author points out that the new British rare earth industries may require government assistance, either direct or indirect, to maintain their position when peace is declared.

*The deposits in the United States have not been worked for several years, due to severe foreign competition.

Notes on Metallurgical and Chemical Engineering in Great Britain

(By our London Correspondent)

The Ministry of Science

The creation of a Ministry of Science, is a proposed suggestion which has the support of many leading commercial and scientific men in this country.

Professor Donnan, F.R.S. of University College, London, in describing the functions of such a ministry proposes that it should establish national laboratories and "Bureaus" for standardization and testing of materials, and investigations relating to the scientific development of agriculture, the mineral resources of the country; sanitation and public health; pure food supply; and the application of science to military and naval matters.

It would also encourage the higher grade schools and possibly provide schools for the scientific training of journalists "so that there shall be produced men who are able to understand, follow and continuously present the results of scientific technical development and scientific inquiry to the readers of the daily Press." In this last projected activity it would almost seem that we should be more nearly imitating the country always referred to by practical men for the excellence of its technical journals, rather than the one whose scientific attainments have been drummed into our ears for the last seven years—very vigorously for the last two.

The Prussian Educational System

Commenting on the contention that the "Prussian educational system had . . . great virtues," a leader in the *Times* educational supplement for August 1, very pertinently points out that the object of that system is "to produce automata for the service of the state, with the inevitable result that the passions of the victim, which are at least as much the true subjects of education as brain-power, are in restraint waiting and watching for the moment when license becomes possible." Seldom has a more clear-headed summing-up of the real objects of education been made, even though prefaced by the supposition that the object of the Prussian system of education was to produce automata for the service of the state. The fact that education should aim at fitting the subject for contending with the problems and difficulties of life, and that the capacity and time of the subject are limited seems never to penetrate the superconsciousness of the political educationist.

The Daylight Saving Scheme

The ease with which the country has adapted itself to the daylight saving scheme has cast considerable doubt on the validity of the ancient maxim "You cannot make a man virtuous by Act of Parliament." (Ref. *Virtue and Early Rising.*) In view of the hoped for commercial activity in the future, it seems at least arguable that the diatribes of scientific men against our present mixture of weights and measures should be reinforced by the enactments of authority. The condition of the manufacturer who has to transcribe all measurements into a duodecimal system, ending in three places of decimals, is not conducive to getting ahead of the rival who simply passes orders and plans through to his shops without any such preliminary. At present, however, we do not seem to have reached even the stage of appointing a committee on the subject. When this was raised as a query in Parliament at the end of July, the answer was that "the compulsory use (of the metric system) was not under contemplation by the Board of Trade." We may take comfort, however, from the fact that the necessity for some alteration has been

noticed by at least one of our legislators in the midst of other pre-occupations.

Electrolytic Hypochlorite

Although the valuable disinfectant and sterilizing properties of solutions containing electrolytic hypochlorite of sodium or magnesium are widely known in the States, and to chemists on this side, they take a considerable time in being discovered commercially. That being so, it is satisfactory to note that the installation for producing electrolytic hypochlorite of magnesium established ten years ago at Poplar, is still supplying the solution and assisting to gain public confidence in its qualities.

The depot distributed last year 73,970 gal. of disinfectant. (Report of the medical officer of health to the Borough of Stepney, Dr. F. W. Alexander, to whom the incidence of the enterprise is principally due.)

Tantalum Used in Interrupter

Apparently the old trouble with the interrupter on the high frequency circuits pertaining to X-ray installations has not yet been entirely overcome, to judge by the continual issue of new forms. A new interrupter was described by Capt. C. E. S. Phillips at a recent meeting of the Physical Society of London. This employs tantalum instead of copper segments, which have the advantage of not retaining a film of mercury, as well as high melting point.

The Society of Chemical Industry

The annual general meeting of the Society of Chemical Industry was held at Edinburgh on July 19, 20, and 21. Dr. Charles Carpenter of the South Metropolitan Gas Company, was re-elected president. In his address he gave attention to the final problem, and the question of state control and organization of the coal resources of the country. The first paper, by Professor Armstrong, was on "Fuel Economy," and the second on "Waste in Coal Production," by Professor Henry Louis.

The general tendency of the conclusion reached was in the direction of central generating stations preferably at the pit mouth for the distribution of energy recovered from coal.

An exhibition showing the progress of certain branches of chemical industry was held at the meeting. This included coal tar colors by the British Dyes, Ltd., and glass and porcelain chemical apparatus by various manufacturers in England and Scotland. A variety of chemicals made in this country were also on exhibition, including alkaloids, oil shale distillation products, cobalt blue (from Canadian ore) and trinitro toluene.

The National Physical Laboratory

The report of the executive committee of the National Physical Laboratory has recently been issued, and shows, as was to be anticipated, that a large amount of the work undertaken has been of a special nature for the government. Particulars of this are naturally not at present for publication. Besides the usual comparison of private instruments with standards, and testing of those required for sub-standards, investigation work not of a confidential nature has been carried on, including an inquiry into means of adequate protection of X-ray workers, in the direction of obtaining the absorption coefficients of materials used for protective purposes. The laboratory was invited to undertake this work by the Council of the Roentgen Society, and arrangements have now been made to do so.

The small tungsten arc lamp of Messrs. Giriningham and Mullard made by the Edison & Swan Co. has been adapted, in larger sizes to optical pyrometer work, as a source of radiation and promises to give very satisfactory results in the saving of time as compared with the use of furnaces.

It is necessary to record the death of Sir William Ramsay on July 23. As many obituary notices will have already reached the States, further record of the widespread regret in scientific and other circles will be superfluous. Sir William Ramsay was a man of many and unexpected accomplishments, and there must be many spheres of activity and usefulness the poorer for his decease.

Market Prices for July, 1916

Copper opened at 103.10.0, being then inclined to fall, and went off gradually till the 6th (£97) after which it fell sharply to £91 on the 7th. On the 10th it had reached £85, and then recovered in two days to £93, but did not retain this price, and showed £88 on the 18th. Again hardening, it had risen to £97 by the 25th and closed at £111.

Tin opened at £172 and was up to £173 by the 6th; it showed weakness on the 11th, but kept somewhere near the £170 mark till the 17th, when it reached £166.10.0, and was down to £163 on the 19th, but recovered, reaching £168.10 on the 21st, but eased off to £166 on the 25th. It subsequently again started rising and closed at £172.

Lead opened at £29.10, and continued easier till the 14th, when it had reached £27; it then recovered to £29.5 by the 19th and closed at £29.

Hematite is quoted 122/6 inland and 140/- export.

Cleveland is quoted 87/6 inland and 95/- to 100/- export.

Scotch Pig.—No prices.

Aluminum cuttings, ton (approximate)	£110	0	0
Borax, British refined crystal, ton	30	0	0
Copper sulphate, ton	51	0	0
Ebonite rod, lb		3	0
India rubber, Para fine, lb		2	10¼
Mica in original cases, medium	3/6 to	5	0
Quicksilver, Spanish, bottle	17	17	6
Sal-Ammoniac, ton	75	0	0
Shellac, cwt.	5	11	0
Sulphur, sublimed flowers, ton	15	0	0
Gutta percha, fine, lb		6	10
Sulphate of ammonia	17	15	0

Recent Metallurgical and Chemical Patents

Electrolytic Cleaning of Silver.—According to a patent of JOHN B. HOEN of Philadelphia, Pa. (assigned to The Frank A. Rolling Co., Inc.) silverware may be cleaned by placing it upon a tinned grid in the bottom of a container; the grid being supported by and in metallic connection with a circular zinc electrode. An electrolyte prepared with bicarbonate of soda and common salt is used, with warm or hot water. It is stated that owing to the quick polarization of the tinned wires and the high overvoltage of the tin, the total flow of current from the zinc to the tin when no silverware is present is relatively small. Oxides, sulphides, etc., which constitute the tarnish, are readily reduced. (1,182,173, May 9, 1916.)

Composition for Metal-Coating of Iron.—A combination of a metal with mercury bichloride, to be used as a protective metal coating, is patented by JAMES H. MADDY of New York City, and BRUNO H. SCHUBERT of Weehawken, N. J. The coating material is made by adding 5 parts by weight of mercury bichloride and 10 parts of ammonium chloride to 100 parts of zinc chloride solution, having a strength commercially known as 50 per cent. This solution is mixed with the powdered metal to form a paint or paste, and applied to the surface of the article to be coated by

a brush, and is then melted on by means of a hot blast. A heat sufficient to melt the coating metal will produce the required adhesion of the coating. The composition is applicable to the coating of articles too large to be dipped. (1,183,217, May 16, 1916.)

Use of Ammonium Sulphate in Making Carbon Articles.—According to a patent of ARTHUR T. HINCKLEY of Niagara Falls, N. Y. (assigned to the National Carbon Co., Cleveland, Ohio), the addition of 5 to 15 per cent of ammonium sulphate to a mixture of coke and pitch increases the density of the final product obtained by baking. It also permits of the use of more pitch binder, prevents swelling while baking, and shortens the time required for coking the binder. Carbon articles are usually made by molding, tamping and forcing them into the desired form from a material or mixture consisting of an agglomeration of coke or other carbonaceous material and pitch. The mixture from which the articles are made is prepared by agglomerating coke, coal or other carbonaceous material with pitch, both being preferably in a powdered condition, in a vessel which is heated sufficiently to melt the latter. Sulphur has been used for a considerable time to increase the density of the baked article, but the action is not so marked as with ammonium sulphate, or other sulphates, as mentioned in the present process. (1,192,062, July 25, 1916.)

Finely Crystalline Abrasives.—In the ordinary process of making artificial corundum the fused alumina is built up into a large ingot of from two to five tons in the furnace. The shell of the furnace is removed after the ingot solidifies and then it is broken up and crushed to the various sizes required for abrasive purposes. According to a new method described in a patent of FRANK J. TONE of Niagara Falls (assigned to the Carborundum Co.), the molten material after being brought to a high degree of fluidity is tapped out in small masses and quickly frozen. This quick freezing produces a finely-grained product. It is necessary to remove the product quickly from the furnace by means of a tapping spout. The product made by quick cooling when examined by the naked eye appears exceedingly dense and almost devoid of physical structure. The general average grain size is about 0.1 mm., as compared with an average of 0.5 mm. in the ordinary product. The special features which characterize the finely crystalline product from the regular product of the same chemical composition are: the finer average grain and the more general distribution of the small amount of opaque material (consisting of compounds of iron titanium and silicon) through the mass, and the relatively smaller size of the tabular type of Al_2O_3 crystals showing parting or cleavage lines. The fineness of the grain makes the abrasive more resistant to breaking forces than the larger grain material. (1,192,709, July 25, 1916.)

Aluminous Abrasives from Waste Garnet.—A process for the electric furnace production of abrasives from finely pulverized garnet ore, occurring as waste in garnet works is patented by JOHN DAVENPORT of Brighton, Mass. The process is described as having been performed on almandite from Wilmot, N. H., having the following composition:

Silica	36.90
Alumina	39.84
Iron Oxide	18.80
Calcium oxide	1.65
Magnesium oxide	3.27
Manganese oxide	0.51
	100.97

Incidental to the production of the abrasives is the production of ferrosilicon. The process consists in heating the garnet flour in an electric furnace with carbon, with the production of oxide of aluminium and a ferrosilicon alloy. The furnace in which the process is carried out is shown in Fig. 1. It consists of an outer iron shell 1, lined with fire brick and having electrodes 5 and 16 as shown. An opening, 13, is provided for the escape of gases and an opening, 14, for feeding in the charge. The charge, consisting of garnet and powdered coke intimately mixed, is fed into the furnace, which is started in the usual manner. Usually 18 per cent of carbon is added. Alternating current of low voltage is used. The action of the arc rapidly reduces the mixture with which the furnace is charged to a molten state since the pure garnet fuses at the relatively low temperature of about

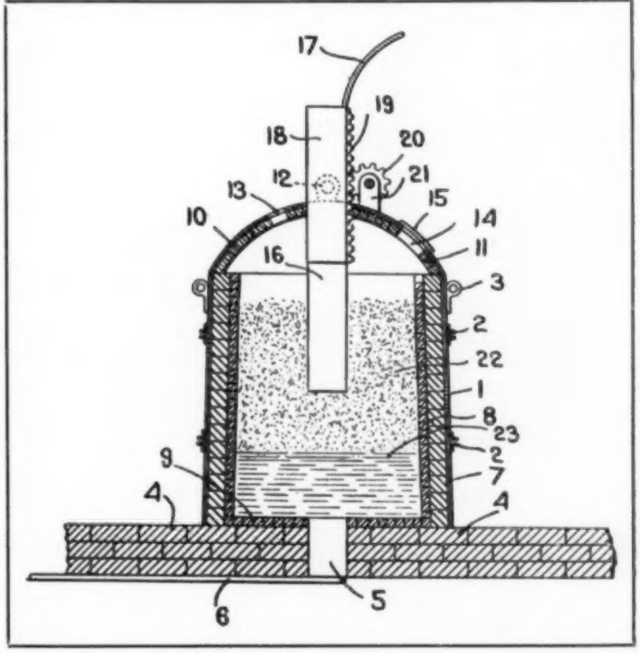


FIG. 1—ELECTRIC FURNACE FOR ABRASIVES AND FERROSILICON

1260 deg. C. The fusing temperature varies with the amount of ferrous impurities contained therein, being lower in proportion to the greater amount of iron contained in the mixture. Additional material may be introduced until a sufficient amount of molten material is found to be present in the furnace. During the reducing operation an active ebullition occurs, considerable gas being driven off. As the reducing operation proceeds the amount of current is gradually increased until the temperature within the furnace reaches the fusing point of alumina, which is approximately 2050 deg. C. When this temperature is reached it is maintained until the constituents other than alumina are entirely reduced and the ebullition ceases. The current is then slowly cut down, gradually decreasing the temperature to permit the slow crystallization of the alumina. It was found that when the molten mixture is cooled rapidly it produces a tough glassy substance which is not properly crystallized and does not form a good abrasive, but that when the molten mass is cooled slowly the alumina becomes crystallized throughout. The ferrosilicon alloy collects in the form of lumps or nodules at the bottom and throughout the mass which may be separated readily from the alumina after the latter is broken. When the entire mass is cooled sufficiently the furnace may be dismantled to

permit the mass to be broken up into pieces of suitable size to be crushed in the usual crushers for abradants. This may be accomplished by lifting off first the dome, then the iron shell 1, after which the bricks may be removed to expose the solid mass of alumina. This mass may then be broken by sledges or in any suitable manner and afterward run through the crusher and graded. The ferrosilicon may be removed from the crushed material by a gravity separator of the Sutton, Steele & Steele type and may be packed for sale to the steel foundries. By adding silica to the original charge or during the reducing operation aforesaid or by using pulverized garnet ore in which the binder contains silica a higher percentage ferrosilicon may be formed, and other substances, such as salt (NaCl,) may be added to the charge to facilitate the fusing and to produce a purer alumina, but ordinarily this is not necessary as the garnet is in itself sufficiently rich in silica and iron for the complete success of the process as outlined. (1,192,394, July 25, 1916.)

Reduction of Sulphur from Sulphur Gases.—A process of recovering sulphur from sulphur gases in which gaseous or liquid reducing agents are used instead of

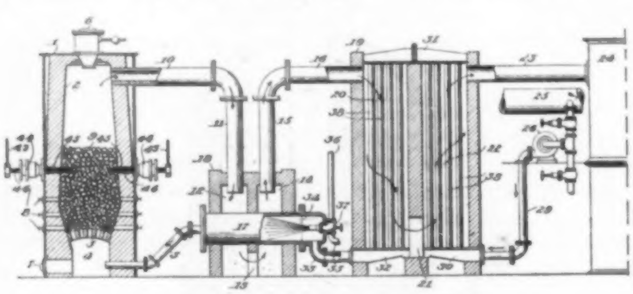


FIG. 2—SULPHUR RECOVERY PROCESS

solid carbon as heretofore is patented by WILLIAM F. LAMOREAUX of Isabella, Tenn. In a previous patent, No. 1,140,310, May 18, 1915, of Lamoreaux and Renwick and application No. 6909, filed Feb. 9, 1915, a process was described in which sulphur-bearing gases are reduced by the action of incandescent coke or charcoal. The coke or charcoal is either heated by electricity or the gases are sufficiently preheated. In the present process sulphur-bearing gases are mixed with a determined amount of reducing agent such as carbon monoxide, hydrogen, hydrogen sulphide, or other vapors or atomized liquids obtained by volatilizing, atomizing, distilling or carbureting petroleum, bitumen, asphalt, etc. This mixture is then passed through a mass of incandescent carbon, which is heated by electricity. The carbon furnishes the heat necessary for reduction, but is not used up to any extent in the process. Apparatus in which the process may be carried out is illustrated in Fig. 2. Sulphur-bearing gases from a main 25 are drawn into pipe 29 by the fan 26 arranged as shown. The gases then pass to a recuperative chamber 19, in which they pass through pipes 38. The exit gases from the furnace pass in an opposite direction on the outside of pipes 38 in spaces 22, giving up some of their heat to the incoming gases. The incoming gases then pass through pipe 33 into mixing chamber 17, which is built in a brick enclosure 18, which is also a pre-heater. The reducing gas or liquid is blown in at 37. After being mixed the gases pass through pipe 3 into the furnace and up through coke, which is heated by electrodes 46. The sulphur is reduced and passes out with the other gases through the recuperative system and then to condenser 24, where the sulphur is recovered. (1,182,915, May 16, 1916.)

Apparatus for Burning Cement and Recovering the Dust.—Apparatus for burning cement and recovering the dust from the kiln gases is patented by HARRY J. SEAMAN of Catasauqua, Pa. Powdered coal is used. The kiln is of the usual construction, consisting of a lined cylindrical shell of steel, placed in position slightly inclined from the horizontal. The cement material is fed in at the upper end and the powdered coal nozzle and hot air nozzle which comprise the burner are at the other end. The coal drops from above into the hot air nozzle and is blown into the kiln where it burns. The gases from the kiln pass first to a compartment, designated as a separator. In the separator the gases pass through vertical steel tubes 10 to 15 in. in diameter and 10 to 20 ft. high. In the center of each tube conductors are placed, connected with a source of high tension current, thus forming an electrostatic separator. The gases give up some of their heat in the separator to air, surrounding the tubes and passing in an opposite direction. The particles of dust are driven outward toward the walls of the tube and adhere to them or fall below to a screw conveyor, which removes the dust from the several tubes to a common collecting chamber. From this separator the gases may go to a bag house, and from there to a "scrubber" or gas washer, in which the gas is passed through streams of falling water. The air which is passed through the separator, as mentioned above, to cool the gases passing through the tubes, becomes heated, and after passing through the separator is led under pressure to the hot air nozzle of the kiln burner, where it is used to force the powdered coal into the kiln and aid in its combustion. (1,185,136, May 30, 1916.)

Automatic Steel Hardening and Tempering Apparatus.—An apparatus for hardening and tempering thin, flat steel articles is patented by FRANKLIN D. FRISBEE and MALCOM H. BAKER of Boston, Mass., and assigned to the American Electric Process Steel Company of Boston, Mass. The process involves the use of several electromagnets and is substantially as follows: A number of the thin, flat articles to be treated are arranged in a row in a receptacle, at one end of which is an electromagnet, operating intermittently through a commutator. This magnet when energized draws one of the articles to a slot in the bottom of the receptacle, through which it drops when the current in the magnet is shut off by the commutator. The piece then falls between two heating heads, faced with platinum and also constituting electromagnets controlled by the commutator. When the piece is between the heads, the heads close and compress the piece, at the same time heat is supplied to the heads by gas burners. After being heated a sufficient length of time, the commutator releases the piece and it drops between two other water-cooled heads, faced with silver and operated in the same way, which cool the piece. The piece is then dropped to a tempering head, or dropped into a tempering bath, which completes the treatment. The operation is entirely automatic and the timing is arranged by suitably adjusting the commutator. (1,183,809, May 16, 1916.)

Suit Over Acid in River.—The Tennessee Power Co., Chattanooga, Tenn., has commenced suit against the Tennessee Copper Co., and the Ducktown Sulphur, Copper and Iron Works, to recover alleged damages to machinery amounting to $25,000. The complainant alleges that sulphuric acid refuse which was emptied into the Ocoee River, from which the Power Company gets its water, caused some of its machinery to become pitted and ruined.

The Manufacture of Tannin Extracts and the Use of a New Evaporator

The manufacture of tannin and dyewood extracts from the natural raw materials, and the recovery of tannin extract from spent liquors in tanneries, etc., has assumed considerable importance in recent years. Immediately the industry assumed a position of importance it felt the need for chemical engineering control and attention in order both to improve the product and to increase the efficiency of production.

There are five important steps in producing extracts from the raw materials, which to the chemical engineer were obviously open to control, and investigation showed that on the method of carrying out these individual operations depended the question of producing an extract which embodied in the highest degree all the requirements of the tanners, or, on the other hand, one which could barely be termed a tannin extract.

The steps in question are as follows:

1. Suitable maceration of the bark or wood.
2. Correct extraction conditions.
3. Clarification of the extract solution.
4. Concentration of the extract (and in the case of some extracts).
5. Solidification of extract for shipment over long distances.

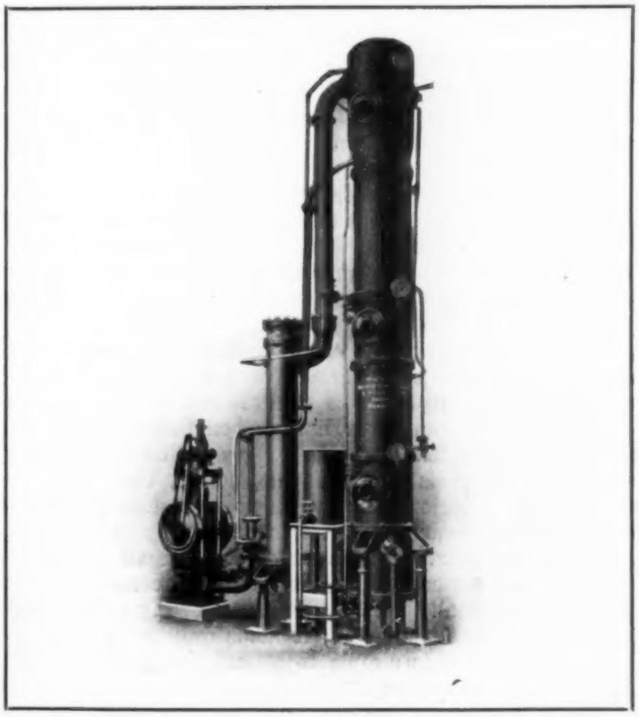
The first question (suitable preparation of bark, etc.), was chiefly the mechanical problem of preparing the material in such a form that with minimum power and handling, the material will be in the best condition for allowing the extraction liquor to remove its soluble tannin content. This has been accomplished without undue difficulty.

The second question was found to be of prime importance to the quality of the product, for by extracting for too long a period or under other variable conditions of temperature, circulation, etc., it was found that many substances soluble or partially soluble under these conditions were extracted with the tannin, and on concentration of the liquor a very impure extract contaminated with coloring matter, non-tannins and even organic acids were obtained. The production of a first-grade extract is now obtained by rigidly adhering to stipulated conditions of extraction.

The third operation, that of clarification of the extract liquor before evaporation, is, of course, patently necessary. To obtain an extract of maximum quality it is obvious that foreign matter such as mud, sludge, chips, etc., be eliminated before the concentration begins. Conditions of clarification vary with the individual raw materials used, and consequently with the various plants in operation.

The fourth step in the process is perhaps the most important, for it is at this point that the grade or quality of extract is made or marred, supposing the preceding operations have been satisfactorily controlled.

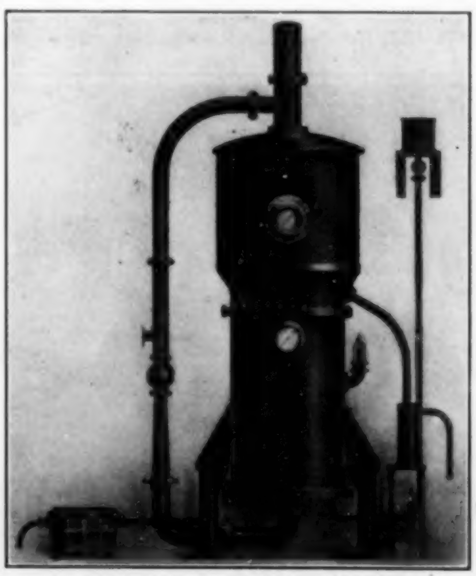
Some liquids on exposure to heat deteriorate rapidly in color. For a long time it was supposed that the cause of this deterioration was entirely due to the temperature, so that many substances were concentrated in vacuum apparatus because the concentration could thus be carried out under greatly reduced heat. Experiments and experience brought out the fact that a sensitive material could stand concentration even at a high temperature if it could be done quickly, that is, if it were not exposed to high temperature for a long period of time.



MULTIPLEX FILM EVAPORATOR, TRIPLE EFFECT

This fact being established, the "multiplex" film evaporator was designed with a view to reducing the temperature by vacuum evaporation, and further to shortening the time that the liquid is in contact with the heating medium. Tannin and dyewood extracts are particularly sensitive as to the effect of overheating. As a consequence of the use of the "multiplex" triple-effect film evaporator, which is described in detail below, the liquid to be evaporated enters continuously in a very small amount and passes through the apparatus in about six minutes, leaving in its concentrated condition.

In cases where solid extract is desired, the concentrated extract from the "multiplex" at say 30 deg. Be., is drawn to a patented "finisher" single-effect pan of special design, or to a modified type of simplex rapid high concentrator. Solidification of the extract is an important economic feature where the product must be shipped a long distance.



THE SIMPLEX RAPID EVAPORATING APPARATUS

Up to within the past few years concentration of tannin, glue, dyewood extracts, etc., has been carried out in only single effect, or at most, double-effect apparatus, in order to reduce the temperature effect. But

even in these conditions the effect of time and mass of liquid was quite noticeable on the color of the product. By the use of a "multiplex" apparatus it is now possible to make use of triple-effect evaporation with its consequent economies of steam, water, power, etc., and obtain a product of prime quality without deterioration.

Even with a "multiplex" high temperatures cannot be totally avoided, but, in consequence of its design, the quantity of liquid contained in each separate "effect" is so small that the liquid remains in it only one to two minutes at most, and is then removed automatically to the next chamber at a lower temperature, and finally after only six minutes or so is drawn off completely concentrated. In the usual evaporator the liquid is not taken from the apparatus for several hours. Most liquids will stand the temperatures of evaporation without injury, their quality only being affected when these temperatures act on them in mass for a considerable time.

The standard type of condenser applied to "multiplex" condensation is such that all the condensed vapor is recovered in a pure state for re-use in extracting, a very important point. The amount of condensing water used is reduced as well as the first cost of the vacuum pump.

In view of the success of the "multiplex" evaporator, a new type has been designed for use in certain conditions where multiple effect plant is not required. The simplex rapid evaporator has proved that even at the temperature of 212 deg. Fahr., prevailing in it, very sensitive materials such as glue, colors, etc., show no perceptible deterioration owing to the short time occupied in evaporation—a few minutes only.

The simplex works at atmospheric pressure, requiring in consequence neither air pump nor condenser. It uses a very small quantity of steam owing to the patent economizer fitted to it; it holds only a small quantity of liquid; it is simple to attend, continuous working, and occupies very little space.

The photographs indicate one of the many uses to which these evaporators have been put in many countries and under varying conditions of operation. These evaporators are built by Messrs. Blair, Campbell & McLean, Ltd., Woodville Street, Govan, Glasgow, Scotland.

An Improved Centrifugal Pump

The development of the steam turbine and the high efficiency multi-stage centrifugal pump have gone hand in hand, but up to the present, it has been difficult to reconcile the speeds of the two machines so that each would work at its best efficiency.

It was necessary, heretofore, to reduce the speed of the turbine and sacrifice much of its efficiency or else speed up the pump with similar results. To overcome this difficulty the Cameron Steam Pump Works, 11 Broadway, New York, have designed and built a multi-stage centrifugal pump, known as the "BT" type.

Fig. 1 shows the construction of one of these three-stage pumps. With the ordinary impeller the diameter cannot be reduced sufficiently to get high speed without sacrificing vane length, and consequently, efficiency for a certain vane length is very necessary in order that the impeller may perform its function without excessive loss. Small external diameter and adequate vane length are obtained in this pump, by bringing the vanes well down into the impeller hub, at the same time so turning them that the incoming water is guided smoothly, and with little loss into the outer portion of the vanes where the velocity is generated that is finally converted into useful pressure by means of the external diffusion vane. Additional advantages in the small impeller are light weight and low fiber stresses in the material.

The casing is divided along the horizontal centerline. Both the suction and discharge connections are in the lower half of the casing. The upper half is readily removable, giving full access to the revolving element. There are suitable openings for draining the pump and for displacing the air when starting. Inlet and outlet nozzles can be arranged either on the same or opposite sides, an important advantage where pumps are installed in limited space.

The shaft is made of high-grade forged steel accurately machined and ground, and wherever it comes in contact with the fluid being pumped, it is thoroughly protected by bronze sleeves, which prevent the stuffing box packing from scoring the surface of the shaft.

Each impeller is cast solid in one piece and is of the enclosed type. Surrounding each impeller hub is a pair of rings, one stationary, attached to the casing, and one revolving, attached to the impeller. By the use of double rings instead of a single ring it is possible to restore the initial tightness of the joint between the low and high pressure sides of each stage without any fitting whatever, whereas a new single ring would have to be of special diameters, and then fitted to the impeller hub, or the casing to make a tight joint.

The diffusion ring surrounds the impeller at its periphery, although it is not in contact with it. It contains a series of openings, which receive the water from the impellers at high velocity and by means of gradually increasing area toward the periphery, reduce the velocity into pressure and enable it to advance to the entrance to the next impeller with much less loss of energy than would be the case if the high velocity of ejection were maintained.

To take care of thrust, which manifests itself in all multi-stage pumps, this pump is equipped with a simple internal hydraulic balancing device. This device consists of a revolving disc attached to the shaft at the inboard or high pressure end. Opposite this disc is a stationary drum of the same diameter. Water at high pressure connects with the space between the disc and the drum, causing the disc to react against the opposing thrust, neutralizing it and holding the rotor in proper relation to the casing. The slight leakage involved in this process is piped back to the suction.

On this pump, there are two ring-oiled bearings, self-aligning, one located on each side of the casing. The bearing bodies are horizontally split, with removable caps, and the bushings are also split and lined with high grade bearing metal. Bushings and bearings bodies

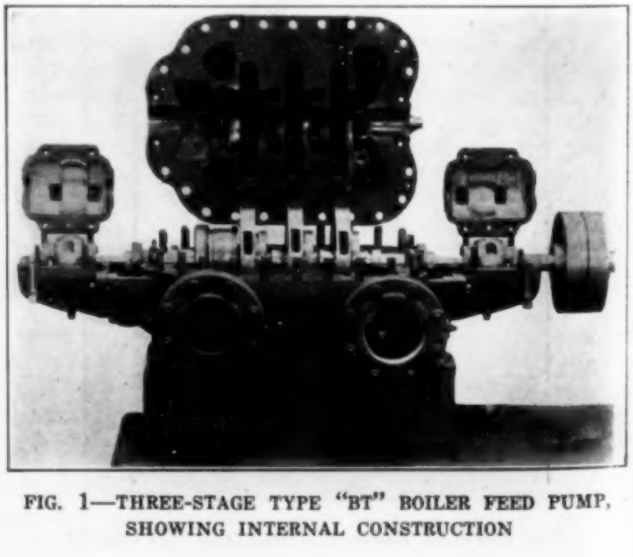


FIG. 1—THREE-STAGE TYPE "BT" BOILER FEED PUMP, SHOWING INTERNAL CONSTRUCTION

have a spherical fit, automatically maintaining the alignment of the shaft. The bearings are of ample proportions to prevent heating, and the oil chamber is of liberal capacity. The bearings are supported by strongly ribbed brackets, cast integral with the lower casing, thus counteracting any possible tendency toward vibration. These brackets are located sufficiently distant from the stuffing boxes to permit of adjustment of the glands. Felt washers are provided to prevent oil escaping from the bearings.

The stuffing boxes are deep and provided with water seals, consisting of a lantern gland in each box, connected to the water from the discharge side of the pump, through a concealed passage, so arranged that it can be readily cleaned. The stuffing box gland is fitted with swing bolts to give quick and easy access to the stuffing box. When the pump is direct-connected, it is supplied with a shaft coupling of the flexible type, to compensate for slight variation in alignment. The bedplate under the pump is of one piece box construction heavy enough to give a rigid support, and with cross ribs to prevent distortion.

Several of these pumps are now being built for the U. S. Government.

A Heat-Treating Plant Using Surface Combustion

A novel heat-treating plant is now being completed at the works of the Eddystone Ammunition Corporation, at Eddystone, Pa., by the Surface Combustion Co., of Long Island City, N. Y., to operate on artificial gas, on the surface-combustion principle. Surface combustion consists essentially in blowing a mixture of air and gas onto refractory material producing complete and flameless combustion on the surface of the refractory.

The theory of surface combustion and the conditions necessary for its actual operation were discussed in a paper at the International Engineering Congress in San Francisco in 1915 by C. E. Lucke, the inventor and original patentee of the process. (See this journal, Vol. XIII, p. 729, 1915.) See also Vol. XII, p. 325, 1914.) Considerable experimental work has been done by the Surface Combustion Company during the last two years on the commercial development of this process and a mixer for air and gas has been developed which maintains automatically constant mixture proportions of air and gas and eliminates all motors, blowers and air piping. This automatic mixer is a feature which has contributed largely to the successful development of the process. It is simple in design and consists of two concentric pipes. Through the annular space between the two pipes the gas passes under pressure, while through the inner pipe air is sucked in in constant proportion. This constant proportion of air to gas is independent of the gas pressure. The principle is somewhat the same as that of a Bunsen burner.

The installation at Eddystone consists of three units of one hardening and one tempering furnace each, comprising a total of six furnaces. Two units are now in operation and the third is being completed. The furnaces are approximately 22 ft. long, 8 ft. wide, and 7 ft. high, outside dimensions, and were designed for a capacity of 5000 shells, 3 in. diameter and 8½ in. long per twenty hours per unit. The furnaces have cast-iron casings built up in small sections for easy replacement. They are lined with ordinary fire brick backed up with 1¼ in. of sil-o-cel brick.

In Fig. 1 is shown the charging end of a hardening furnace, back of which to the left can be seen the tempering furnace which goes with it. Fig. 2 shows the other end of this furnace with the oil quenching bath. Fig. 3 shows a longitudinal section and Fig. 4 a cross section of the furnace.

The shells are placed on a sliding tray in front of the small holes shown and at regular intervals are moved into the furnace by the piston of the air-pressure cylinder shown. As one row is charged the whole line of material on the hearth of the furnace is moved along and one row leaves the other end of the furnaces dropping through a chute down into the oil bath, shown in Figs. 2 and 3.

It was the intention to have the material taken from the oil bath by conveyors, and one is shown in Fig. 2, but at present this work is being done by manual labor, pending the design of a more successful conveying system.

The material is treated for one hour at 1550 deg. Fahr. in the hardening furnace, and after being quenched is dried on a drying table and is then charged into the tempering furnace which is similar to the hardening furnace. The material is drawn at 1150 deg. and afterwards air-cooled.

Running through each furnace are eight steel angles which act as troughs to carry the shells. A man stands in front of each furnace and feeds shells into the angle troughs. Every two minutes the pusher pushes the shells ahead the length of a shell. This causes eight shells to discharge into the oil-quenching bath located at the discharge end of the hardening furnaces, from which they are taken when sufficiently cool and fed into

FIG. 1—HARDENING FURNACES, CHARGING END

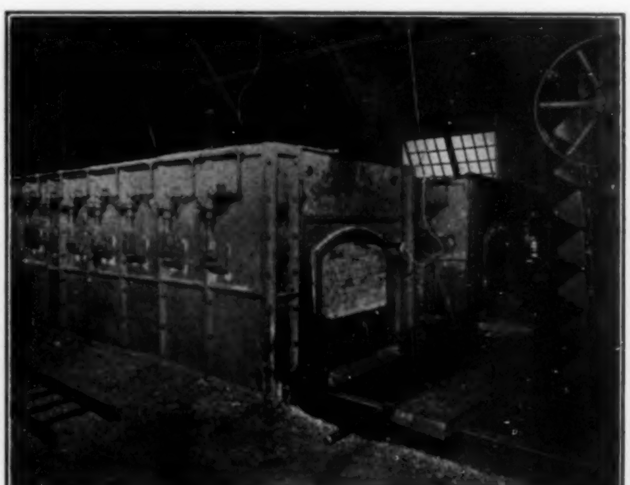


FIG. 2—REAR OR DISCHARGING END

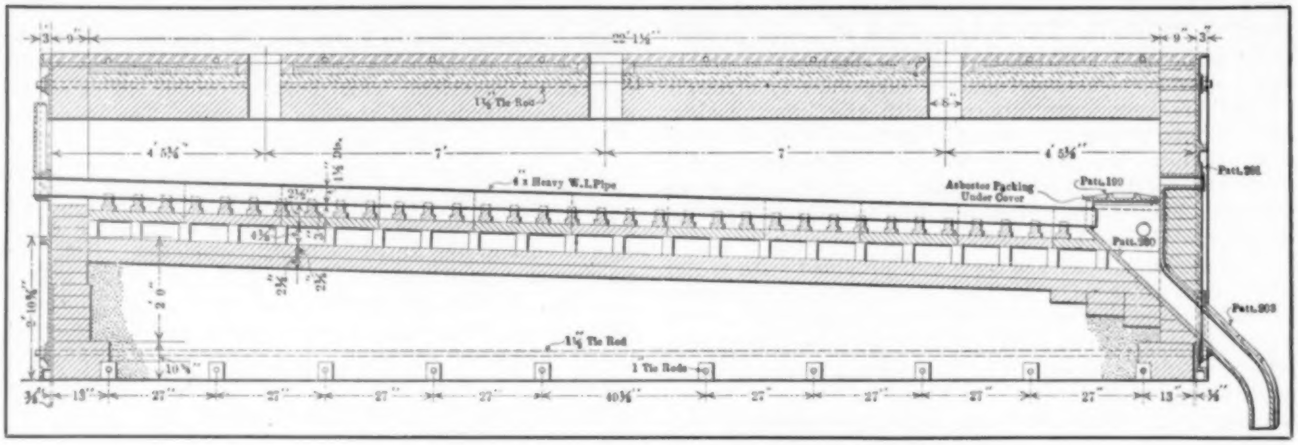


FIG. 3—LONGITUDINAL SECTION OF HARDENING FURNACE

the tempering furnaces in exactly the same manner. The furnace hearths are on a slight slope—$8\frac{1}{2}$ in. in the total length—and in the last two furnaces now being completed it has been decided to give the same slope to the roof of the furnace, thus making the hearth and roof parallel. In the other furnaces the roof is horizontal.

The gas is blown downwards as shown in Fig. 4, on to broken alundum where the combustion takes place. Carborundum has also been used for this purpose. The heat is radiated from this broken alundum up to the sides and top of the furnace and from there to the work. The design of the nozzle can be seen in Fig. 4. The end of the nozzle is surrounded with fire-resisting material to protect the nozzle from the heat and the flares on the nozzle just outside the furnace wall also help in cooling the nozzle.

The furnaces are as air-tight as possible. To prevent leakage in of cold air, which would produce an oxidizing effect and by its cooling action would lower the furnace efficiency, a slight furnace back pressure is maintained. As in all surface-combustion work the furnaces are so designed as to develop and utilize the maximum possible amount of radiant heat. The flues are arranged so as to distribute the hot gases uniformly and to release them at the lowest possible temperature. The hardening furnaces are equipped with 22 high-pressure burners, and the tempering furnaces with 18. All piping is laid in conduits having removable covers, thereby eliminating all overhead work. Each burner is fed by a $\frac{1}{2}$-in. pipe from a 1-in. manifold.

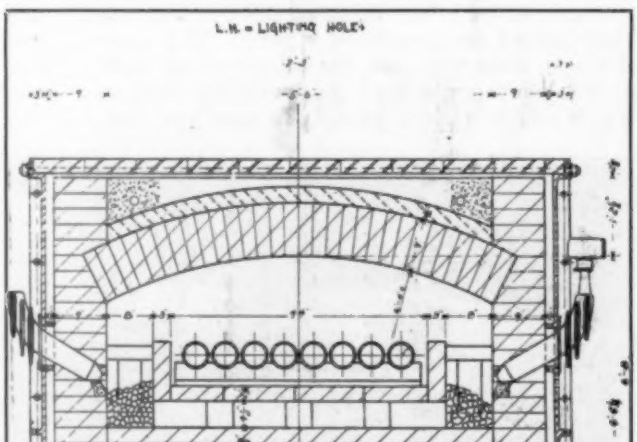


FIG. 4—CROSS-SECTION OF FURNACE

Frequent flue gas analyses have shown that it is possible to have oxygen = 0.0, carbon monoxide = 0.0, and an average of 15.2 carbon dioxide. This shows that the heat may be generated with 100 per cent efficiency having no excess air or unburned gases. For the purpose of minimizing the scaling of the shells and to lengthen the life of the angle troughs, the furnace is operated with a slightly reducing atmosphere, carbon monoxide reading between 0.3 and 0.5. This is done to be on the safe side, as an oxidizing atmosphere would be very injurious in this operation.

All of the furnaces are controlled from a central control pulpit. Each furnace is controlled by a single valve which regulates the pressure supplied, and thus the temperature. The maximum pressure is 25 lb. and the minimum 5 lb. The average operating pressure is 15 lb.

Temperatures are taken by Brown electric recording pyrometers, one at each end of each furnace. All pyrometers are located in the central control pulpit. This allows one man to easily operate all of the furnaces. This feature has resulted in considerable saving of labor. As frequently as many as eight men have been necessary to care for burners and the control of temperatures on a similar number of furnaces of the same size, fired by oil. This feature also allows much more accurate and careful control as evidenced by the practically straight-line pyrometer charts which are secured daily.

There is also located in this pulpit the electric flasher, which times the charging operation. This machine flashes a red light in front of each furnace every two minutes, which flash is the signal for the men to operate the pushers.

Gas is furnished by the Philadelphia Suburban Gas & Electric Co. of Chester, Pa. Each unit consumes an average of 3300 cu. ft. per hour. The approximate average cost of the gas is 43 cents per 1000 cu. ft. It is furnished on a sliding-scale rate.

Several oil-fired furnaces operating on fuel oil costing 0.045 per gallon of practically the same size and doing the same work were in operation prior to the installation of these furnaces. One of these oil-fired furnaces was carefully tested, over a period of several days, the oil being measured in a calibrated tank. Subsequent tests of the gas-fired furnace showed a lower operating cost on this work.

A New Important Installation of Pulverized Coal Under Stationary Boilers

When during the winter of 1912 the natural gas supply was limited in quantity and fuel oil hard to obtain in Kansas, the Missouri, Kansas & Texas Railroad Company officials decided to investigate other methods for generating steam in their boilers at the power house of their new shops at Parsons, Kan., where eight 250-hp. O'Brien boilers of the Heine water-tube type were installed with equipment for using only natural gas and oil as fuel. Some of the other fuels available in the district which would be within an economical range as to cost delivered at their plant were soft coals from the mineral mine in Kansas, McAlester and Lehigh mines in Oklahoma, and lignite from Texas, with the following government analysis as received:

Kind of Coal	Fixed Carbon	Volatile Matter	Ash	Moisture	B.t.u. Value
Mineral	45.22	26.39	20.38	8.01	10640
McAlester	47.07	32.37	14.29	6.27	11837
Lehigh	41.40	31.28	19.29	8.03	11200
Lignite	25.50	33.95	7.58	32.97	7548

The sulphur separately determined ranged from approximately 3 to 5 per cent in the various soft coals.

Owing to the ash and moisture content of these available fuels, it was determined by the Missouri, Kansas & Texas Railroad officials to investigate the method of using these fuels in a pulverized form, as they were aware of the fact pulverized bituminous coal had been in constant use in the cement industry, in a major portion of the plants throughout the country, and on many industrial furnaces for years, and the method of preparing this fuel eliminated almost all of the moisture before injection into the furnace, thereby obtaining the highest possible B.t.u. value in the firebox from the fuel, instead of the loss that would obtain if used in the old way, by hand-firing or stokers, with fuel ordinarily received from the cars, as it was found cheaper to drive off this moisture in dryers designed for the purpose.

During this investigation the Missouri, Kansas & Texas Railroad officials found the Fuller Engineering Company of Allentown, Pa., had made an exhaustive study of fuels in pulverized form, designed and built coal-pulverizing plants throughout the world, and had already operated boilers with pulverized coal, and they were therefore engaged to design and construct what in their opinion would meet the requirements of these fuels.

After several conferences with Mr. Kellogg, superintendent of motive power of the Missouri, Kansas & Texas Railroad, the contract for this entire installation was signed and given to the Fuller Engineering Company of Allentown, Pa., on May 1, 1913, at Parsons, Kan., and all material and machinery was fabricated and delivered in Parsons in the fall of 1913, but in the meantime, owing to financial conditions, it was thought wise not to make the change at that time.

In the early part of 1916 orders were given to proceed with the work. The work was started in the spring, completed, and put into successful operation on Aug. 1, 1916.

Various tests were made with the different fuels mentioned above, and all of them were burned with entire success, showing no destructive effect on the firebrick walls of the furnace, but giving a most effective distribution of the heat throughout the several passes of the boiler and exceptional heat absorbtive effects throughout the heating surface of the boiler with low stack temperatures. No deposit of ash settled any-

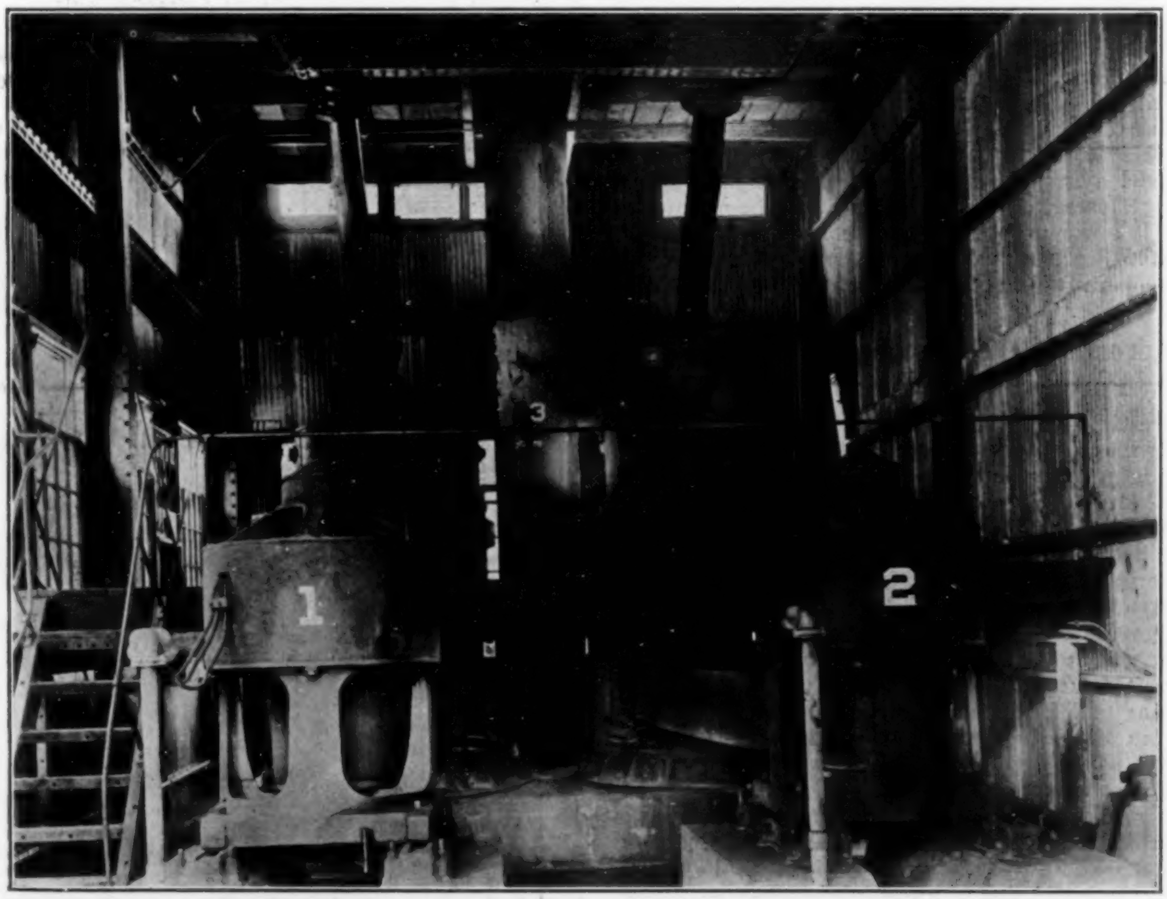


FIG. 1—42-IN. FULLER-LEHIGH PULVERIZER MILLS IN COAL PLANT AT PARSONS, KAN.

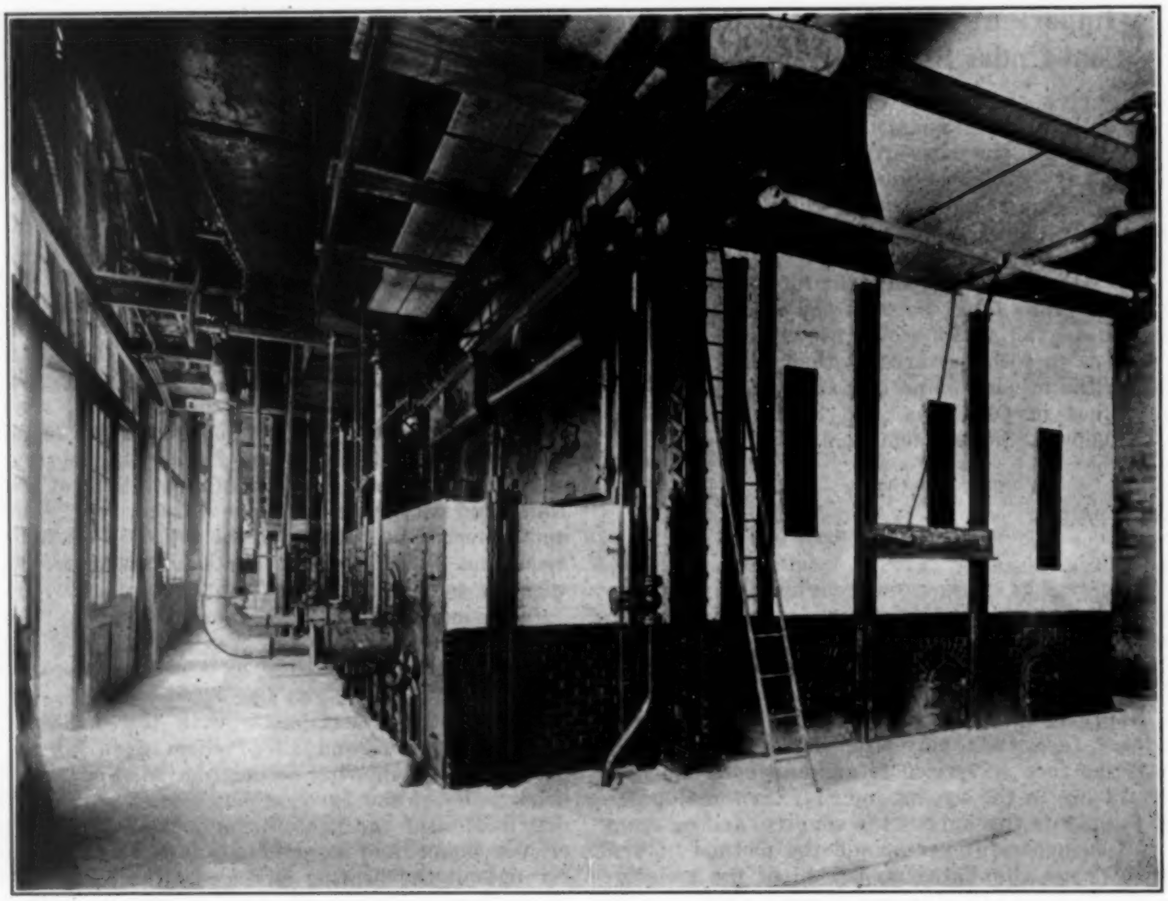


FIG. 2—VIEW OF O'BRIEN TYPE WATER TUBE BOILERS OPERATING ON PULVERIZED COAL AT PARSONS, KAN.

where in the boiler but what was readily dislodged with an ordinary air blast. The evaporation obtained with 16 per cent CO_2 in the stacks was 10.7 lb. of water per pound of combustibles from and at 212 deg.

As this is the first large installation of pulverized coal under a complete battery of boilers, the two accompanying illustrations of the plant should be of interest. Fig. 1 is a view of the 42-in. Fuller-Lehigh pulverizer mills, and Fig. 2 a view of the O'Brien type water-tube boilers operating on pulverized coal at Parsons, Kan.

Interesting Developments in Domestic Porcelain Ware Manufacture

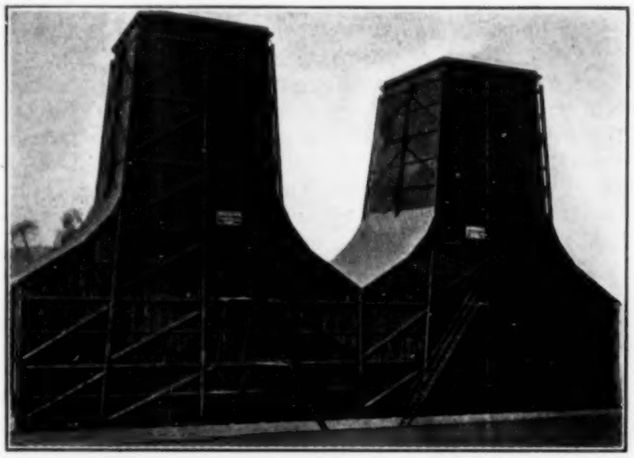
Interesting developments are occurring in the chemical porcelain ware industry in this country. The industry is growing very rapidly, and the manufacturers who have undertaken to supply this country's demands for high-grade porcelain ware, which was mostly imported before the war, are certainly to be congratulated on their success. They deserve the encouragement and support of our chemists, chemical industries, and of the government.

Two large pieces have been recently made by the Guernsey Earthenware Company, Cambridge, Ohio, consisting of a retort and evaporating dish. These are shown in the accompanying illustration. The retort measures 34 in. high, 34 in. diameter, 20 in. across the top, 20 in. across the bottom, 16-in. opening at top, and has a capacity of 30 gal. The evaporating dish measures 11 in. high, 28 in. diameter, and has a capacity of 10 gal. These two pieces are claimed by the makers to be the largest pieces of chemical porcelain ware made in America up to the present time. The Guernsey factory now has a capacity of approximately 5000 pieces per day of chemical laboratory porcelain, and arrangements are being made to increase this to 10,000 pieces per day.

LARGE CHEMICAL PORCELAIN PIECES MADE IN AMERICA

A Large Cooling Tower

What is believed to be the largest natural draft cooling tower so far built has recently been completed at the Anderson, Ind., plant of the American Steel & Wire Co. This tower is of the Wheeler-Balcke type built by the Wheeler Condenser & Engineering Co., of Carteret,



LARGE COOLING TOWER AT AMERICAN STEEL & WIRE CO.

N. J. The tower is approximately 150 ft. long, 50 ft. wide and 75 ft. high and has a yellow pine frame with cypress sheathing and filling. The tower, as shown in the accompanying photograph, has two chimneys which rise above the cooling stacks and create the air circulation by natural draft. The capacity of the tower is 7300 gal. a minute cooled from 115 to 85 deg.

Personal

Prof. **Charles H. Herty**, Dr. **W. R. Whitney**, Dr. **L. H. Baekeland** and Prof. **Warren K. Lewis** have been appointed by the American Chemical Society to co-operate with the committee of the National Academy of Sciences on the nitrate question.

Mr. **A. C. Lyon** is in charge of the newly formed General Testing Laboratory at Kansas City, Mo., organized to conduct chemical, physical testing and metallurgical work. Mr. Lyon was formerly for a long time chief chemist and vice-president of the Kansas City Testing Laboratory, and previous to that time he was with the Carnegie Steel Co. The offices and laboratory of the new company are at 1122 Grand Avenue, Kansas City, Mo.

Mr. **William D. Manchester** of Rocky Hill, Conn., has been appointed superintendent of the crushing department of the Chile Exploration Co., Chuquicamata, Chile.

Mr. **C. R. Pafenbach** has resigned as chief chemist of the Simonds Manufacturing Company, Lockport, N. Y., to take charge of the chemical and metallurgical work of the Covert Motor Vehicle Company of Lockport, N. Y.

Mr. **J. B. Risque** has resigned as manager of the Tennessee Copper Co., and **Mr. N. H. Emmons, 2nd,** has been appointed manager to succeed him.

Mr. **C. B. Semple,** formerly manager of the Chicago office of the Duplex Metals Co., and more recently with the Hazard Manufacturing Company, has been appointed manager of the copper-clad steel department in the Chicago office of the Steel Sales Corporation.

Mr. **Thomas M. Skinner, Jr.,** has resigned as superintendent of the Mid-Continent Chemical Co., of Sand Springs, Okla., to accept the position of assistant manager of the Potash Products Co., Alliance, Neb.

Mr. **Ivan P. Tashof** has resigned as instructor in mining and metallurgy at the College of Mines and Metallurgy of the University of Kentucky, and will enter the practice of patent law with Messrs. Byrnes, Townsend and Brickenstein, of Washington, D. C.

Mr. **J. A. Wilkinson** has been elected president of the Chemical, Metallurgical and Mining Society of South Africa.

Mr. **G. H. Wohlhaupter,** formerly connected with the Utah Copper Co., is now conducting flotation experiments for the Stimpson Equipment Co., of Salt Lake City.

Industrial Notes

New Electric Heater. — Messrs. Woldenburg & Schaar, Chicago, Ill., have placed on the market a new electric heater for use in the laboratory in heating flasks, beakers and general apparatus. The heater is designed for practically all purposes for which Bunsen burners and hot plates are used. The top of the heater will accommodate a 1-liter flask. For use as a hot plate a metal disc is supplied which fits on the top. For heating test tubes a perforated cylinder is supplied.

New Borax Fields in Chile.—According to a report from the commercial attaché at Santiago, Chile, new fields of calcium borate are said to have been found near Iquique, and that 150 claims, or 18,750 acres, have been solicited. Average values of 15, 20, 30, 40 and 60 per cent of borax are given.

Fuel Testing.—Messrs. Eimer & Amend, New York City, have issued an interesting and valuable booklet on "Fuel Testing Apparatus." The booklet discusses coal-testing methods, the sampling of coal, and gives a detailed outline of procedure for determining heat of combustion of fuels in the Emerson calorimeter. The method of standardizing a calorimeter is also given, together with descriptions of the Parr calorimeter and accessory apparatus required for fuel testing, such as electric furnaces, electric ovens, pyrometers, grinding machines, etc.

The **Crocker-Wheeler Company,** Ampere, N. J., announces that its San Francisco district office, of which Mr. W. K. Brown is district manager, has been removed from the Crossley Building, 619 Mission Street, to the ground floor of 37 New Montgomery Street. A large assortment of motors, generators and transformers will be carried in stock for the convenience of buyers of electrical equipment on the Pacific Coast.

Aluminium and Bauxite In 1915.—The production of bauxite in the United States in 1915, according to a recent Geological Survey report, was 297,041 long tons—an increase of 35 per cent over 1914. This is an abnormal increase and is accounted for by the large increase in the manufacture of aluminium. The figures for the consumption of aluminium in 1915 are given as 99,806,000 lb., over 20,000,000 lb. more than consumed in 1914. The Aluminium Co. of America greatly extended its operations during the year and is continuing to expand and increase its production so as to be able to supply the domestic demand, even with all imports cut off.

Large Increase in Lime Used by Chemical Works.—The amount of lime used in 1915 by chemical works increased 34 per cent over 1914, according to figures

gathered by the U. S. Geological Survey. These figures are interesting, as they show the greatly increased activities of our chemical industries. The lime for chemical works represented nearly one-seventh of the total quantity used in 1915. This does not include lime used in smelters, alkali works, glass works, and many other industries. The amount sold to chemical works in 1915 was reported as 492,870 short tons.

Grinding Machinery.—The Colorado Iron Works Co., Denver, Colo., has issued pamphlet No. 31, describing ball and tube mills and grinding pans. The pamphlet is nicely illustrated and contains considerable reading matter of great technical value, including tables of slime density relations.

Fuel in Russia.—The general opinion of Russia is that it is a country very much backward industrially, and from other points of view. It is well known, however, that enormous natural resources are contained in the country. Since the war started Russia has had to rely on its own resources. According to the Chemical Trade Journal and Chemical Engineer the condition as to fuel is, however, quite serious.

That which in normal times, and more than ever now, renders difficult the distribution of fuel in Russia is the absence of means of communication, and, above all, the lack of rolling stock. It is to this lack that Russia owes her economic torpor, and her finding herself at the present time, from the point of view of the supply of fuel, in a somewhat distressing condition. As on the other hand very severe restrictions on the cutting down of forests have been prescribed, the employment of wood as a substitute for coal has been rendered very difficult.

The situation has, however, been relieved by the utilization of the petroleum with which the country is so abundantly provided, and particularly by the use of the residues from distillation. From January to September, 1915, the shipments of naphtha and its derivatives by the Volga exceeded by 33 per cent those of 1914. This supplementary use of oil may be reckoned as 80 million poods, which, on a colorific value of 10,000 calories, would correspond to about two million tons of coal.

Until about 1910 Russia restricted herself to the production of coke without recovering the by-products, valuable for so many purposes. At the end of 1913 the number of recovery coke ovens in the whole of Russia was 848. Their output (for the whole of 1913, for six months only of 1914 and 1915) was as follows:

	In Poods 1913	1914	1915
Coke	79,550,000	....	....
Tar	2,410,300	1,439,000	1,656,000
Ammoniacal liquor (25%)	1,014,000	558,000	628,000

The production of coke in the Donetz region was 278 million poods in 1914 and 251 millions in 1915. It will be seen that two-thirds of the coal are still carbonized without the recovery of the by-products.

Russia is the most important producer of oil in Europe, and the second in the world, the United States being the first. The principal center is situated in the Baku region. The Russian production has not, however, in the last ten years had the intensive development that has characterized the American and Roumanian production. While the world's output has increased from 29,775,000 tons in 1906 to 57,920,000 tons in 1914, the Russian production has only passed from 8,168,000 to 9,173,000 tons in the same space of time. There was a slight increase for 1915, 13 million poods more than in 1914, the yield being 9,348,000 tons.

Book Review

Niagara, Queen of Wonders. By **Edward Theodore Williams.** 188 pages, profusely illustrated. Price, $2.00. Boston: Chapple Publishing Co., Ltd.

This is a most interesting book, a graphic history of the development of Niagara in three centuries. The author is the president of the Niagara Frontier Historical Society and has been for eleven years managing editor of the *Niagara Falls Journal*, and for five years industrial agent of Niagara, N. Y.

The author first takes up the early history of the Niagara frontier, beginning with the struggle between the French and English for control, the occupation of Fort Niagara by the United States, and the war of 1812. A letter by Peter Kalm, dated Sept. 2, 1750, reprinted as being the first account of the Falls in English, is a charming human document.

The author next discusses the "free Niagara" project. Up until 1885 the shore of the Falls was occupied by so-called squatting interests who taxed visitors to the limit. In 1885 the New York legislature passed a bill appropriating money to acquire necessary land including islands near the Falls to make a public park and thus make the Falls free to all. The bill was passed on recommendations of a commission.

The first real power development, the hydraulic canal, was commenced by Horace P. Day in 1853 and finished in 1861. He spent a lot of money and was not successful. It was not until 1875 that it was successfully used. The canal was purchased by Jacob F. Schoellkopf of Buffalo, in 1877, and the original Hydraulic Power & Mfg. Co. formed in 1878. Three generations of the family have been in control ever since. Dynamos were installed by this company in 1881. In 1895 they commenced power station No. 2 which has since been superseded by station No. 3, one of the finest in the world. Most of this company's power is used in electrochemical and electrometallurgical work.

The development of the Niagara Falls Power co. is next taken up, beginning with the granting of the charter by the N. Y. legislature in 1886, which gave them the right to develop 120,000 hp. from one tunnel and 100,000 hp. from another. Owing the federal restructions the second tunnel was never constructed. The first power was delivered by this company on Aug. 26, 1895, to the Pittsburgh Reduction Co., now the Aluminum Co. of America, which company now uses 75,000 hp. The allied company, the Canadian Niagara Power Co., was also formed at this time. At present the American company furnishes 106,000 hp. and the Canadian company 112,500 hp.

Details of the growth of the City of Niagara Falls, N. Y., are next given, with a list of the important plants. The great question of diversion is taken up, including a discussion of agitation against further development, the findings of the International Waterways Commission, the passage of the Burton Act in 1906, limiting diversion of water on the American side, and Secretary of War Taft's opinion after his hearing at Niagara in 1907. The Burton law requested the President to open negotiations with Great Britain and a treaty was effected in 1910, for five years, terminable on 12 months' notice.

The author is strongly in favor of further diversions and many data are given to show that scenic grandeur will not be destroyed. A discussion of Federal vs. State control is also included.

Taken in the whole, the book is very suggestive reading and contains much that will be new even to those who have been fond of Niagara and Niagara history for years.